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Study of an ATC Baseline for the Evaluation of Team Configurations: Information Requirements

Ben Willems, ACB-220
Michele Heiney, Ph.D., Northrop Grumman Information Technology
Randy Sollenberger, Ph.D., ACB-220

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16. Abstract

This study investigated the information needs of Air Traffic Control Specialists (ATCSs) relative to their working position. The working positions used in this study included the current radar ATCS position and the concept airspace coordinator position. Thirty current Certified Professional Controllers from Air Route Traffic Control Centers within the Continental United States volunteered to participate in a human-in-the-loop experiment. ATCSs worked in teams of three, either on a radar, upstream data, or airspace coordinator position. Within the team of three, two ATCSs always worked on a radar position, while the third rotated through radar, upstream D-side, and airspace coordinator positions. After they had controlled simulated air traffic on a high fidelity simulation of the Display System Replacement System, the participants answered a detailed Information Requirement Questionnaire (IRQ). The IRQ asked about types of radar, flight, and weather information needed for future automation functions for the radar and airspace coordinator positions. The future automation functions included conflict probe, resolution, and trial planning, direct routing advisory, flight path monitor, and load smoother. The participants indicated that the airspace coordinator needed different information from the automation than the radar ATCS. They also rated the importance of the automation functions differently depending on the ATCS position that would use them. Therefore, we need to take into account the roles and responsibilities of the ATCS when deciding the format and amount of information displayed on automation tools.

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Executive Summary

In an ongoing effort to improve Air Traffic Control (ATC), the Federal Aviation Administration (FAA) continues to integrate automated tools into the National Airspace System (NAS). These automation tools should improve safety and efficiency, while enabling Air Traffic Control Specialists (ATCSs) to control more aircraft and provide user requested routes. Several research groups have suggested that the FAA can make further improvements in the NAS through the introduction of a new operational planning position that has responsibilities for identifying more efficient flight paths and solving potential losses of separation across multiple sectors. No studies have evaluated ATCS reaction to some of these new automated tools or the relevance of specific information provided by a tool for use by either the traditional Radar (R-side) ATCS or a new multi-sector position. In this study, we evaluated the information needs of ATCSs to maximize performance of assigned duties. We also evaluated the specific types of information that would make various automated tools more effective given the roles and responsibilities of the ATCS position (i.e., an R-side ATCS or a new multi-sector ATCS).

We collected ATCSs' ratings for the importance of certain information following a human-in-the-loop simulation. The simulation examined the effectiveness and feasibility of implementing a new multi-sector ATCS position without automated decision support tools and within the context of the current NAS. We manipulated the role of our participant ATCSs by assigning them to either the North or South R-side sectors or the Experimental Position. In the experimental position, the ATCS rotated between an R-side, Upstream Data (D-side), or Airspace Coordinator role. On the questionnaire, ATCSs responded to the information needs of the R-side or Airspace Coordinator roles. We also asked about what types of flight, radar, and weather information ATCSs perceived to be important for the displays of conflict probe, conflict resolution, and trial flight planning (CP); direct routing advisory; flight path monitor (FPM); and load smoother (LS) functions. We used automation as a separate independent variable, where appropriate.

Thirty ATCSs from Air Route Traffic Control Centers within the United States voluntarily participated in the experiment conducted at the William J. Hughes Technical Center in Atlantic City International Airport, NJ. ATCSs completed an Information Requirements Questionnaire (IRQ) following human-in-the-loop simulations in which teams of three ATCSs acted as either individual R-side ATCSs, two R-side ATCSs with an Upstream D-side assisting one of the R-side ATCSs, or two R-side ATCSs with a shared Airspace Coordinator assisting both sectors. The IRQ asked, in detail, how important specific flight, radar, and weather information would be to either an R-side ATCS or an Airspace Coordinator while fulfilling the tasks and duties of the given position. ATCSs could then use their experience from the simulations in which one of the three ATCSs acted as an Airspace Coordinator. The ATCSs conceptualized future automation functions from detailed descriptions provided during the briefing. These briefings did not specify how a function would display relevant information.

Our participant ATCSs differentiated between the information and automation function needs of an R-side ATCS and those of an Airspace Coordinator. ATCSs indicated that most types of flight, radar, and datablock information are important with a few exceptions (e.g., fix posting, departure airport, and aircraft beacon code). However, the role of the ATCS and the automation function affected the importance of specific information. ATCSs indicated that, although

important for both ATCS roles, the CP function was more important for R-side ATCSs, whereas the LS function was more important for Airspace Coordinators. ATCSs indicated that the Computer Identification (CID) was more important for R-side ATCSs than for Airspace Coordinators when using the CP, whereas detailed aircraft information and "hot spots" were more important for the Airspace Coordinator than for the R-side ATCSs when using the LS function. This reflects the difference in the positions' roles and responsibilities. R-side ATCSs have tactical control of aircraft with the primary goal of directing aircraft in a safe, conflict-free manner. Any automation function that assists the R-side in detecting potential conflicts would be of great assistance. The R-side needs to know which specific aircraft are involved (i.e., specific aircraft identification information) and the CID information because R-side ATCSs enter control actions into the system via the CID. In contrast, the Airspace Coordinator is not tactical and has multiple sectors to ensure safe but direct routes for aircraft and coordinates through sector R-side ATCSs. The LS function becomes more important for them, along with detailed information about the aircraft in the "hot spots." The Airspace Coordinator would then use this information to clear up congested areas through control requests issued through the sector ATCSs.

Our results indicate that in future studies, it is necessary to provide participants with an implementation of the automation functions under investigation. Our participants indicated that the automation functions might require different implementations depending on the roles and responsibilities of the ATCS that uses them.

1. Introduction

In an ongoing effort to improve Air Traffic Control (ATC), the Federal Aviation Administration (FAA) continues to integrate automation tools into the National Airspace System (NAS). These automation tools need to improve safety and efficiency to enable Air Traffic Control Specialists (ATCSs) to control more aircraft and accommodate user requested routes. In addition, several research groups have suggested that the FAA can make further improvements in the NAS through the introduction of a new operational planning position. The National Aeronautics and Space Agency (NASA), MITRE's Center for Advanced Aviation System Development (CAASD), and Eurocontrol have proposed different implementations and operational procedures for a new ATCS position. As conceptualized by these agencies, the new multi-sector position would use the various automated tools to make air traffic more efficient and to solve potential losses of separation (LOSs) strategically. However, no studies have evaluated ATCS reaction to some of these new automated tools or the relevance of specific information provided by a tool for use by either the traditional Radar (R-side) ATCS or a new multi-sector position. In this study, we evaluated the information needs of ATCSs to maximize performance of assigned duties. We also evaluated the specific types of information that would make various automated tools more effective given the roles and responsibilities of the ATCS position (i.e., an R-side ATCS or a new multi-sector ATCS).

1.1 Background

The use of automation in ATC is not new, and ATCSs use various automated tools in the current NAS (e.g., RADAR, host, and Display System Replacement [DSR]). The FAA's Office of Air Traffic System Development (1997) plans to develop and implement more automated tools. The Office of Air Traffic System Development provides an outline to test and then widely deploy new tools. Some of these newly designed automation features include Conflict Probe, Conflict Resolution, and Trial Flight Planner (CP); Direct Routing Advisor (DRA); Flight Path Monitor (FPM); and Load Smoother (LS). The goal of all these automation functions is to increase the ATCS's ability to handle increased traffic levels while improving safety and efficiency.

Beside changes to equipment, NASA, Eurocontrol, and MITRE's CAASD have proposed procedural changes that include the introduction of a multi-sector level ATCS as part of a multi-layered ATC system. The goal of these proposals is to provide a maximally efficient flight path for each aircraft from departure to arrival. Maximizing an efficient flight path involves getting each aircraft on the optimal trajectory as soon as possible and minimizing deviations from that trajectory. Automated decision support tools (DSTs) are necessary to fully take advantage of a Multi-Sector Planner (MSP) position.

Several studies have investigated alternative team configurations in ATC and decision support automation tools (e.g., Latron, McGregor, Geissel, Wassmer, & Marsden, 1997; Louden, Lawson, Thompson, & Viets, 1999; Micro Analysis and Design, Inc. & System Resources Corp. [SRC], 2000; Nicolaon, De Jonge, Maddock, Cazard, & McGregor, 1997a, 1997b; Thompson, Hollenberger, & Taber, 1999; Vivona, Ballin, Green, Bach, & McNally, 1996). Unfortunately, most of the studies have not addressed ATCSs needs regarding the type of required information automated tools should present. Further, they have not addressed whether

there are differences in needed information between an R-side ATCS and a multi-sector ATCS position. The goals of these two positions contrast and, therefore, the information needed to successfully perform the job may be different.

We first discuss, in Section 1.1.1, automated DSTs. Section 1.1.2 provides information about the current sector-based control responsibilities in the NAS. In Section 1.1.3, we discuss information about proposed trajectory-based control responsibilities.

1.1.1 Automated Decision Support Functions

In future ATC systems, automation will play an important role in supporting ATCSs with relevant information and advisories. With this anticipated support, ATCSs will be able to manage increases in air traffic without experiencing an increase in workload or a reduction in situation awareness (SA). In this baseline study, we have introduced two positions that could benefit from these automation functions. We asked our ATCS participants their opinion on information requirements for several automation functions that they may encounter in future automation systems. In our queries, we deliberately stayed away from specifying how a function or tool would display relevant information. Our Information Requirement Questionnaire (IRQ) asked the ATCS participants about CP, FPM, DRA, and tactical LS functions. In this section, we will briefly discuss each of these automation functions as they currently exist in the field or will exist in the near future.

The underlying concept that makes each of these four functions possible is the four-dimensional (4D) trajectory. A 4D trajectory extends beyond the traditional flight plan in that it includes the flight plan itself, aircraft characteristics, probabilities about the quality of track data, and weather information (e.g., MITRE/CAASD, 1999). A particular decision support system creates a 4D trajectory for each aircraft known to the system. We refer to this process as trajectory synthesis.

Conflict Probe, Conflict Resolution, and Trial Planning advisories use the 4D trajectories to test if aircraft are likely to violate minimum separation standards. A conflict probe does so by comparing every aircraft trajectory against one another. Within given constraints, the conflict probe function reports its findings to the ATCS. Currently, conflict probe functions are capable of predicting potential conflicts accurately up to 20 minutes before the closest point of approach. (citation). A conflict resolution advisory function would use the outcome of the conflict probe and test system-generated solutions to the potential conflict against existing trajectories. The conflict resolution advisory function then reports scenarios to the ATCS that are likely to solve a pending conflict without generating new conflicts. Finally, the trial planning function works similar to the conflict probe with the difference that an ATCS can create a hypothetical flight plan for an existing aircraft based on the ATCS' plan for that aircraft. The trial planning function compares the hypothetical trajectory against all existing trajectories and reports its findings to the ATCS.

The **Flight Path Monitor** monitors the existing 4D trajectories for each aircraft in the system and tests if an aircraft stays within its 4D trajectory. If an aircraft diverts from its 4D trajectory more than predefined boundary conditions, the FPM alerts the ATCS (e.g., Barrow, 2000).

Direct Routing Advisories use the 4D trajectory to determine if an aircraft can fly to its destination along a shorter route (e.g., McNally, 2000). If the system finds a route that saves more than a predefined number of miles or minutes, it will test the new trajectory against existing trajectories. If the shorter route is conflict free, the system reports the new route and the savings to the ATCS.

The Tactical Load Smoothing function uses existing trajectories and conflict probe results to determine local traffic complexity (Meckiff, Chone, & Nicolaon, 1998). Eurocontrol used this function for their MSP position. Then LS calculates the complexity based on equations that include the number of aircraft in a given volume of airspace, the aircraft mix, and other factors. The tactical LS function presents the information to the ATCS by displaying a contour map of traffic complexity. ATCSs can then focus on a complex situation in a particular area and determine which aircraft is the main contributor to that situation. In a system developed by Eurocontrol, an ATCS could also run "what-if" scenarios to determine what a change in the flight plan for one aircraft would do to the overall traffic complexity contours.

1.1.2 Current Sector-Based Control Responsibilities in the National Airspace System

The ATCS has the primary responsibility for the separation of aircraft within a specified airspace (sector) in the current en route ATC system. The ATCS uses a number of tools to help maintain separation between aircraft including the radar display and the flight progress strip (FPS). The ATCS uses these tools to develop and maintain an understanding of the air traffic situation. The ATCS actively manages air traffic within a sector using specific knowledge of the current situation and general knowledge of ATC. The ATCS plays an active role in the current ATC system in that pilots must follow all ATCS instructions and assigned flight plans. Only with the approval of the ATCS or in an emergency can the pilot make changes to the cleared heading, altitude, route, or speed. Essentially, the ATCS is in complete command.

In the current NAS, the focus of ATC responsibilities is the sector. A sector is a volume of airspace with a lateral boundary, a floor, and a ceiling. ATCSs operate tactically within that airspace. Rarely do sector ATCSs plan traffic flows or conflict resolutions much outside the borders of their sector. Within an Air Route Traffic Control Center (ARTCC) sector, ATCSs can work

- alone as an R-side ATCS,
- as a two-person team consisting of an R-side ATCS and a D-side ATCS, or
- as a three-person team consisting of an R-side ATCS, a D-side ATCS, and a Radar Associate ATCS position (a tracker).

The R-side is the primary position responsible for ensuring aircraft separation. In general, in the current environment, the D-side assists the R-side in tactical control. Appendix A provides the current ATCS responsibilities by position according to FAA Order 7110.65L CHG1 (FAA, 1998).

1.1.3 Proposed Trajectory-Based Control Responsibilities in the National Airspace System

Several researchers suggest that ATC must move from the sector-based to a trajectory-based approach to improve system efficiency (e.g., Couluris, 2000; Leiden & Green, 2000). In a trajectory-based approach to ATC, ATCSs no longer control aircraft solely with separation and efficiency within a sector in mind, but rather across all sectors on the aircraft's flight path. The trajectory-based approach considers the full trajectory of each aircraft. Because of the focus on the full flight path from airport of origin to airport of destination, the trajectory-based approach may save fuel and reduce delays. Leiden and Green reviewed several candidate sector configurations that would encourage a trajectory-based approach over the current sector-based approach (Table 1). We briefly discuss the inter-sector planning options with their advantages and disadvantages.

Table 1. Inter-Sector Planning Options

User Request Evaluation Tool-like procedures
Upstream D-Side
Upstream R-Side
Upstream Team
NASA Airspace Coordinator
Multi-Sector Planner

The first approach for more trajectory-based control uses User Request Evaluation Tool (URET)-like procedures. This approach relies on information provided by one DST, URET. URET is the interim conflict probe currently in use at Memphis and Indianapolis ARTCCs that uses a "downstream[1]" concept. In this concept, the downstream team where a pending conflict will occur has the option to reach out to upstream sectors that currently control the aircraft and coordinate changes to aircraft trajectories to solve pending problems before aircraft enter the sector. URET is a D-side tool and, in essence, shifts the D-side into a role that becomes more strategic. An advantage of using URET-like procedures is that URET uses an existing position (the downstream D-side) without changing existing procedures. Although the D-side ATCS in the URET environment has a new tool, the D-side's primary responsibility is to assist the R-side ATCS. In complex traffic situations, therefore, the D-side ATCS joins the R-side in a tactical capacity, and the planning function is most likely sacrificed just when it is needed most. The use of a strategic tool would only play a secondary role in that case. Another limitation of URET is that it provides the downstream D-side with a time horizon of 20 minutes for pending conflicts.

The upstream D-side reverses the URET-like procedures. Now, the upstream sector owns the conflict instead of the downstream sector. The upstream D-side now has the additional responsibility to resolve pending conflicts in downstream sectors by changing trajectories of aircraft that are currently in his or her sector. The advantage of this approach is similar to the URET-like procedures; the D-side position already exists and operational procedures do not need to change. The main change that would need to occur is a change in the ATCS mindset. In the

[1] A downstream sector is the sector in which a conflict is predicted to occur without any control action to resolve it. An upstream sector is the sector in which aircraft are flying when a predicted conflict is identified in the downstream sector.

upstream D-side concept, the D-side will need to tell the R-side to move aircraft because of pending conflicts in downstream sectors. The current ATCS culture perceives the D-side as assisting the R-side ATCS. In the current system, the presence of a D-side often means that the traffic situation is so complex that the R-side ATCS needs assistance. The additional multi-sector responsibility for the D-side may take the needed assistance away from the R-side ATCS. Without a change in the position requirements for the D-side, it is likely that the D-side ATCS will drop the strategic planning to assist the R-side ATCS. Further, the upstream D-side concept would require a change in staffing procedures, putting a D-side ATCS on every staffed sector.

The upstream R-side reverses the URET-like procedures as well. The upstream sector has the responsibility for resolving a conflict instead of the downstream sector. In this case, the R-side now has the additional responsibility to resolve pending conflicts in downstream sectors by changing trajectories of aircraft that are currently in the sector. The advantage of using an existing position still exists, but it comes with a major disadvantage. The R-side is a tactical ATCS working with a short time horizon and needing to react to tactical situations. The strategic role of the upstream R-side does not fit within the tactical responsibilities of an R-side ATCS. When the complexity of a traffic situation increases, the R-side ATCS will likely drop secondary tasks like solving conflicts downstream. An additional disadvantage is that in many of the ATC centers, sector staffing with a single ATCS is the norm except for when traffic complexity dictates otherwise.

The upstream team concept puts the responsibility of resolving downstream conflicts on the ATCS team. The advantages and disadvantages of the upstream D- and R-sides still hold true for the upstream team. Similar to the D-side concept, the upstream team concept would require a change in staffing.

A new position that would take advantage of the existing operational procedures is the Airspace Coordinator proposed by NASA. The Airspace Coordinator monitors several sectors for potential aircraft conflicts and more efficient traffic routes. The Airspace Coordinator can only put control actions into effect by coordinating with the sector-based ATCSs through the regular channels. An advantage of this concept is that ATC has experience with positions that have fulfilled functions similar to the Airspace Coordinator such as a floating "tracker" (i.e., a third ATCS that would be used to assist a two-person team, when needed). Another example is the floating D-side ATCS; he or she has a similar function as the floating tracker but assists sectors staffed with a single ATCS when needed. Finally, some ARTCCs have Traffic Management Unit (TMU) staff that will "walk the floor" to actively assist in moving aircraft to maintain an efficient flow of traffic. A possible disadvantage of this position may be that it could increase the workload of the R-side ATCS because of an increase in landline communications.

Finally, Eurocontrol introduced the concept of an MSP. The MSP has the responsibility to monitor a group of sectors. In this role, the MSP actually issues advisories and control instructions directly to aircraft via data link. The control instructions (e.g., speed, heading, and altitude changes) become effective at the border of a sector. Eurocontrol's PHARE (Van Gool & Schroeter, 1999) project evaluated the feasibility of the MSP position. The MSP received many new tools to assist in fulfilling these new functions and responsibilities. The project's results indicate that the MSP lost SA and suffered from information clutter on the MSP display. It is likely that the MSP had not received enough time to effectively integrate the tools into his or her

new role causing an increase in workload and an associated loss of SA. On the other hand, a multi-sector ATCS may have very different SA requirements than a sector-based ATCS. The MSP, for example, was not responsible for all pending conflicts in the MSP area. The MSP focused on aircraft and their pending conflicts up to 10 minutes before they entered the MSP area. Therefore, if one uses SA measures based on sector-based control, an MSP may lose SA and still have good SA when evaluated based on MSP requirements. An advantage of the MSP function is that it includes the ability to issue control actions to aircraft directly thereby reducing increased use of landlines. The disadvantage of the MSP functions that ATCSs often point out is that the same aircraft now receives instructions from both sector ATCSs and the MSP. ATCSs' most dreaded situation is another ATCS controlling traffic in his or her sector. The main disadvantage of the PHARE project was that it did not separate the effects of the introduction of new tools from the effects of the newly created multi-sector position.

1.2 Objectives

The objective of this study was to identify the information needs required for a multi-sector position and contrast those needs with the needs of the traditional R-side ATCS. We were interested in what types of information ATCSs perceived to be important for the displays of CP, FPM, DRA, and LS functions.

1.3 Scope

We present informational needs data collected during a human-in-the-loop simulation that examined the effectiveness and feasibility of implementing a new multi-sector ATCS position without automated DSTs and within the context of the current NAS. Our focus in the current report is how ATCSs perceived the importance and necessity of various flight, radar, and weather information that various future automation functions would present.

Thirty ATCSs performed en route ATC simulations at two experimental task load levels (Low and High)[2]. The ATCSs worked in team configurations either as 1) individual R-sides (baseline), 2) upstream D-side (in teams of three standard positions consisting of two R-sides and one D-side), or 3) Airspace Coordinator (in teams of three consisting of two R-sides and one shared multi-sector position that could only coordinate through the sector ATCSs). After finishing all experimental trials, ATCSs completed the IRQ (Appendix B) that asked, in detail, how important specific information would be to either an R-side ATCS or an Airspace Coordinator while fulfilling the tasks and duties of the given position. ATCSs could then use their experience from the simulations in which one of the three ATCSs acted as an Airspace Coordinator. They needed to conceptualize the future automation functions from detailed descriptions provided during the briefing. These briefings did not specify how a function would display relevant information.

[2] Although some researchers may question our ability to express task loadin a quantitative way, our subject matter experts can give us their expert opinion on what traffic levels will provide us with low, moderate, or high task load levels as long as we, as researchers, determine what operational conditions we want to mimic with these levels. The number of aircraft in a sector is but one of the variables that determine the task load. Others prefer to use sector complexity rather than task load (Mogford, Murphy, Roske-Hostrand, Yastrop, & Guttman, 1994). Sector complexity is a composite of number of aircraft, type of aircraft, aircraft flight profiles, number of handoffs, and, likely, several other factors. In this experiment, the number of aircraft that move through the sector airspace mostly determines the task load.

2. Method

In the following sections, we describe participants, experimental staff, experimental design, and procedure.

2.1 Participants

Thirty Certified Professional Controller ATCSs (6 female, 24 male) from ARTCCs within the United States voluntarily participated in the study. All participants were current, non-supervisory, full-time ATCSs. They actively controlled traffic at level 11 and 12 ARTCC facilities for at least 16 hours in the month preceding the experiment. To maintain a homogeneous participant pool, we recruited ATCSs that had DSR certification and at least one month DSR experience. None of the participants was on medical waiver or in a staff position at the time of the experiment. The mean age of participants was 39.3 years (31 - 46). They had actively controlled traffic at an en route facility for 11.3 years (2 - 22). The participants worked air traffic for an average of 11.9 (10 – 12) months in the preceding 12 months. Using a 10-point scale, participants rated their current skill level as a 7.9 (5 - 10), their stress level as 4.3 (1 - 8), and their motivation to participate in the study as 8.2 (4 - 10).

The Institutional Review Board of the William J. Hughes Technical Center approved the study, and the ATCSs gave their written consent to participate in the experiment (See Appendix C for the Informed Consent Form). The research team ensured them that their data would be completely confidential.

2.2 Experimental Staff

A research team of two Engineering Research Psychologists (ERPs) administered the IRQ. In preparation for the study, the ERPs designed the experiment, procedures, questionnaires, and briefing. The ERPs managed the experiment, collected data, and directed support staff. After experiment completion, the ERPs performed the data analyses and wrote the final technical reports. The clerical staff assisted in preparing, copying, and distributing forms and questionnaires during the experiment, and prepared means, standard deviations (*SD*s), Multivariate Analysis of Variance (MANOVA), and Analysis of Variance (ANOVA) tables.

2.3 Design

Our study was a 2 (ATCS roles: R-side or Airspace Coordinator) x 3 (ATCS position: North R-side, Experimental, and South R-side) design. We added additional Independent Variables (IVs) depending on the analysis we conducted and present them with the specific dataset. To ensure that the North Sector in the two sector conditions would work enough traffic to justify the presence of D-side ATCS, we created scenarios that were somewhat heavier in the Northern portion of our airspace.

2.3.1 Independent Variables

2.3.1.1 ATCS Position

a. Experimental ATCS

The ATCS assigned to the Experimental Position rotated between three different sets of roles and responsibilities – R-side, Upstream D-side, and Airspace Coordinator. We selected the Upstream D-side and Airspace Coordinator from the candidate sets of roles and responsibilities. The Upstream D-side represented roles and responsibilities that were not substantially different from current responsibilities. This position served as a traditional D-side to the North R-side with added responsibilities for monitoring conflicts and traffic in the downstream sector (i.e., South Sector). The Airspace Coordinator represented roles and responsibilities that included monitoring several sectors of airspace with the goal of identifying potential LOSs and finding more efficient flight routes for aircraft. The Airspace Coordinator then implemented any control instructions through the sector R-side ATCSs. Appendix D contains complete descriptions for the R-side, Upstream D-side, and Airspace Coordinator positions.

b. North R-side ATCS

The North R-side ATCSs controlled traffic as an R-side in all simulation conditions.

c. South R-side ATCS

The South R-side ATCSs controlled traffic as an R-side in all simulation conditions.

2.3.1.2 ATCS Role

On the questionnaire, we asked about two ATCS roles: R-side or Airspace Coordinator. We chose the Airspace Coordinator role from the various multi-sector positions.

2.3.2 Dependent Variables - Information Requirements Questionnaire

The IRQ[3] (Appendix B) contained specific items inquiring about the importance of flight data, radar, and other information that ATCSs would need for future automation functions and for different ATC functions. ATCSs rated the importance of each item using a Likert-type rating scale from 1 (not important) to 10 (very important). These future automation functions included a CP, FPM, DRA, and LS (Table 2). We asked them to differentiate between an R-side ATCS and an Airspace Coordinator (i.e., ATCSs rated the importance of each item for each of the two positions) because each position has different roles and responsibilities and the requirements needed to fulfill these may be different.

[3] In this report, we focus on the IRQ ratings completed by ATCSs after finishing all experimental simulation runs. We also collected data examining SA, workload, visual scanning, and performance during the simulation, but will present results based on data analyses on those constructs in separate technical reports.

Table 2. Automation Function Descriptions

Automation Function	Description
Conflict Probe, Conflict Advisory, and Trial Planning (CP)	Conflict probe – similar to the standard Host conflict alert except that it can use flight plan, weather, winds, and trajectory information to detect conflicts much sooner than the standard Host conflict alert. Conflict advisory – provides ATCSs with control action advisories that will resolve existing conflicts without causing additional conflicts. Trial planning – allows ATCSs to enter a proposed (or hypothetical) control action and have the system project aircraft trajectory to detect potential conflicts or report a clear conflict status.
Flight Path Monitor (FPM)	Monitors aircraft for conformance with flight plans and control instructions and alerts controller to significant unplanned lateral deviations or altitude busts.
Direct Routing Advisory (DRA)	Works in conjunction with an underlying conflict probe function to provide ATCSs with control action advisories that will allow direct routing of aircraft to their final destinations. The function will identify only those aircraft that have direct routes, which are clear of conflicts and will save a "significant" amount of time and/or distance.
Load Smoother (LS)	Identifies the locations of "hot spots" where high aircraft density and complexity exist in a region of airspace. The function uses a specified time in the future and projects where the "hot spots" will appear according to aircraft flight plans, weather, winds, and trajectory information. Once the "hot spots" are identified, the function provides ATCSs with control action advisories for specific aircraft in order to reduce aircraft density and complexity in the "hot spots."

We divided the IRQ into several categories (Table 3). Because we asked the same items for flight, radar, and datablock; assigned control actions; and map display data across all the automation functions, we created a within-subjects variable of automation that contained four levels: CP, DRA, FPM, or LS. For the trial planning questions, we had only three levels of automation: CP, DRA, and LS. Other sets of questions were specific to an automation function and therefore we did not include the created automation variable within these statistical analyses. We discuss the specific type of analysis for each questionnaire item in the Results section.

2.4 Procedure

ATCSs participated in the experiment for 1 week. The morning of their first day of participation consisted of a briefing and a familiarization period. We explained the experiment, differences between experimental and field equipment and the confidentiality of participant identity. During the briefing, we described in detail each of the automation functions included on questionnaires. We provided an informed consent briefing and assurance that participation was voluntary. After completing all experimental scenarios, ATCSs completed the IRQ, and then we debriefed them.

Table 3. Information Requirements Analyses

Category	Characteristics	Created IVs	Type of Analysis
Questions common to all automation functions	Flight Data (Callsign, type/equipage, computer ID, sector control designator, fix posting, departure airport, arrival airport, flight plan en route, beacon coded) Radar & Datablock (location, altitude, heading, airspeed, interim altitude, altitude change indicator, handoff status) Assigned Control Actions (assigned altitude, heading, and airspeed) Map Display Data (sector boundaries, SUA, heavy weather location, VORs)	Automation: CP, FPM, DRA, LS	2 x 3 x 4 (ATCS role x Position x Automation)
Trial Planning Questions	Trial plan conflict status, a/c trajectory, a/c callsigns, a/c trajectories & LOS point, time until LOS, closest-point-of-approach	Automation: CP, DRA, LS	2 x 3 x 3 (ATCS role x Position x Automation)
CP questions only	Conflict alert indicator for involved a/c, a/c trajectory & LOS point, time until LOS point, closest-point-of-approach	Probe Type: a/c, SUA, Weather	2 x 3 x 3 (ATCS role x Position x Probe Type)
CP questions only	Primary and resolution advisory control action for each a/c, a/c trajectory under resolution advisory		2 x 3 (ATCS role x Position)
FPM questions only	Flight path deviation alert indicator, a/c deviation trajectory, a/c planned route, extent of lateral/altitude deviation, lateral/altitude deviation criteria for alert		2 x 3 (ATCS role x Position)
DRA questions only	Primary and alternate DRA control action, a/c trajectory under advisory route, time/distance savings criteria for a/c		2 x 3 (ATCS role x Position)
FPM questions only	Primary and alternate LS advisory control action, a/c trajectory under advisory route, "hot spots" under advisory route for specific times		2 x 3 (ATCS role x Position)

3. Results

For a description of general statistical methods as well as for detailed information about the statistical methods used in this study, we refer the reader to Willems and Truitt (1999).

We computed MANOVAs to compare effects on multiple variables and ANOVAs for effects on single dependent variables (DVs). We tested the Wilks' Λ statistic using a level of $p < .05$ and

report the equivalent F statistic. We report the most commonly used alpha level closest to the actual p value obtained. If the results of the MANOVA were statistically significant ($p < .05$), we performed univariate ANOVAs to determine which of the DVs were significantly different across experimental conditions. We based the significance of an ANOVA result on an adjusted alpha level using the following formula:

$\alpha_{overall} = 1\text{-}(1\text{-}\ \alpha_{individual})^n$ where n is the number of variables

or:

$\alpha_{individual} = 1\text{-}(1\text{-}\ \alpha_{overall})^{1/n}$

We report the adjusted alpha level with each analysis. If the result of an ANOVA was statistically significant, we performed appropriate post hoc tests to determine which conditions were responsible for the significance.

Other researchers have used a more lenient approach when investigating the effects of manipulation on DVs by not adjusting the alpha level. Such an approach may make it more likely to erroneously conclude that an effect exists, but allows researchers to investigate trends in the data. In the current study, we follow such an approach to investigate trends (Table 4).

Table 4. Types of Trends

Trend	**Multivariate**	**Univariate *p* value**
Primary	Significant	< .05, > adjusted alpha
Primary	Not significant	< adjusted alpha
Secondary	Not significant	< .05, > adjusted alpha

In the graphical presentation of the results, we provide means and *SD*s. The *SD*s indicate the between-subject variance. We use this to present the variance among participants. For statistical purposes, we used the repeated-measures variance to determine statistical significance.

3.1 Questions Common to All Automation Functions

We conducted 2 x 3 x 4 (ATCS Role x Position x Automation) mixed measures MANOVAs for the items common to all automation functions. These MANOVAs examined flight, radar and data block, assigned control actions, and map display data items, respectively. We conducted follow-up univariate analyses to examine any significant effects at the MANOVA level and to check for trends. We adjusted the alpha level according to the number of items within a given category. We provide the means, *SD*, MANOVA, and ANOVA tables in Appendix E.

3.1.1 Flight Data

The 2 x 3 x 4 (ATCS role x position x automation) mixed MANOVA examining the flight data items showed a significant effect for role [$\Lambda = .32$, $F(9,19) = 4.58$, $p < .05$, Table E-5] across the set of items. We conducted follow-up ANOVAs and adjusted the alpha to .006.

We found secondary trends for the item regarding aircraft callsign (Table E-9). ATCSs rated aircraft callsign more important for the CP function than for the LS function. The ATCS role x automation interaction reached a trend. ATCSs rated the aircraft callsign information as more important for the CP function than for the LS function when used by an R-side ATCS compared to an Airspace Coordinator. In contrast, ATCSs rated the aircraft callsign information as more important for the LS when used by the Airspace Coordinator than an R-side ATCS (Figure 1). Results for the FPM and DRA did not show these differences.

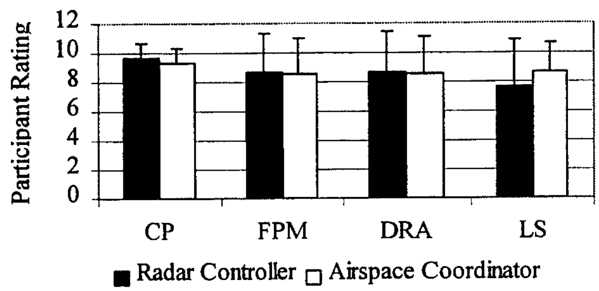

Figure 1. Importance of aircraft callsign by ATCS role and automation.

A secondary trend for the ATCS role x automation interaction occurred for aircraft type and equipage information (Table E-10). ATCSs rated this type of information on the CP function as more important for the R-side ATCS than for the Airspace Coordinator (Figure 2). ATCSs did not rate this information different for the other automation functions.

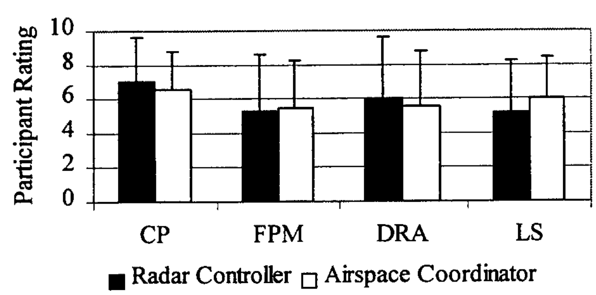

Figure 2. Importance of aircraft type and equipage by ATC role and automation.

We found a primary trend for automation and secondary trends for ATCS role and position for the importance of CID (Table E-11). ATCSs rated CID information as more important for the CP function than for either the DRA or LS functions (Figure 3). The importance of this item for CP and FPM did not differ. ATCSs rated this item more important for R-side ATCSs than for Airspace Coordinators (Figure 4). The Experimental ATCSs rated this information as less important than the South R-side ATCSs, but their ratings did not differ in ratings from the North R-side ATCSs (Figure 5).

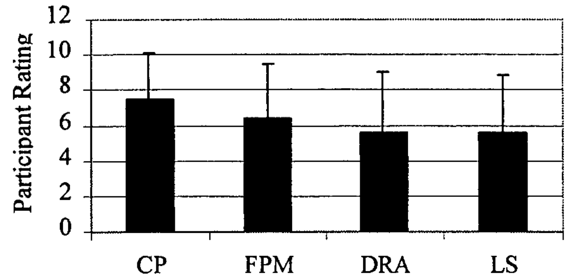

Figure 3. Importance of CID by automation.

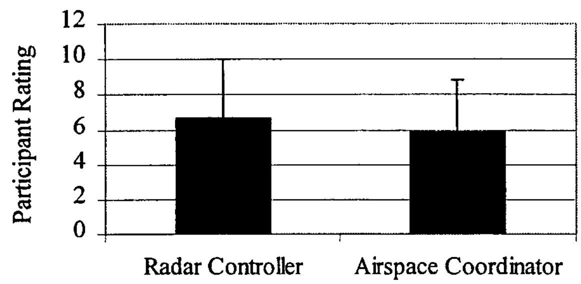

Figure 4. Importance of CID by ATCS role.

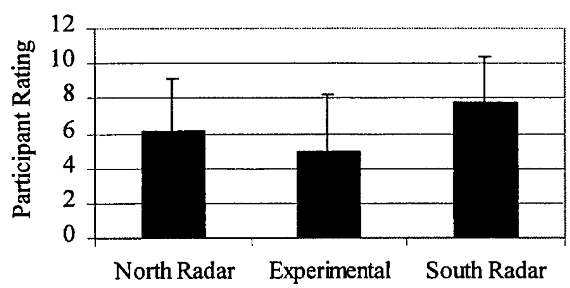

Figure 5. Importance of CID by position.

We found a secondary trend for the three-way interaction for ATCS role x position x automation for the importance of sector control designator information (Table E-12). ATCS role x automation had an effect on North R-side ATCSs' ratings but did not influence either the Experimental or South R-side ATCSs' ratings. North R-side ATCSs rated the sector control

designator as more important for Airspace Coordinators when using the LS than when R-side ATCSs use the LS (Figure 6). They did not rate any of the other automation functions statistically different for either of the ATCS roles. The ratings of the Experimental and South R-side ATCSs did not show this effect (Figures 7 and 8, respectively).

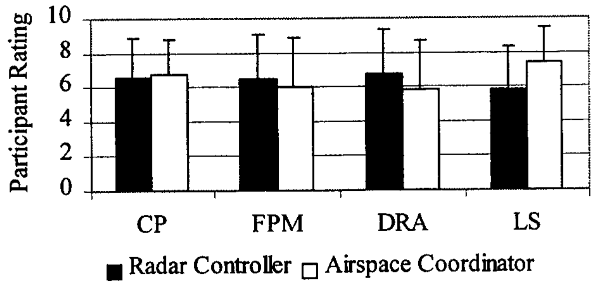

Figure 6. Importance of sector control designator for North R-side ATCS by ATCS role and automation.

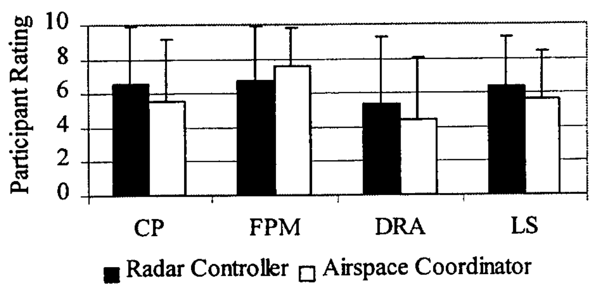

Figure 7. Importance of sector control designator for Experimental ATCS by ATCS role and automation.

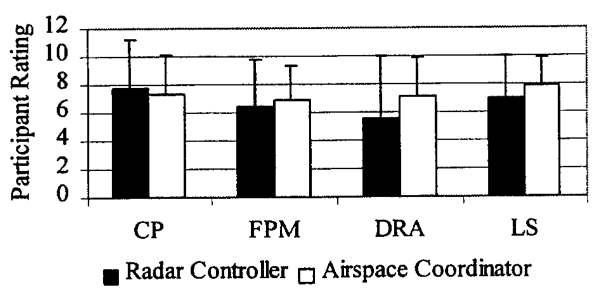

Figure 8. Importance of sector control designator for South R-side ATCSs by ATCS role and automation.

A primary trend for the ATCS role x position interaction occurred for fix posting data (Table E-13). South R-side ATCSs indicated that they felt this information was more important for the Airspace Coordinator than for the R-side ATCS (Figure 9). The North R-side and Experimental ATCSs did not rate this item as more important for either the R-side ATCS or Airspace Coordinator.

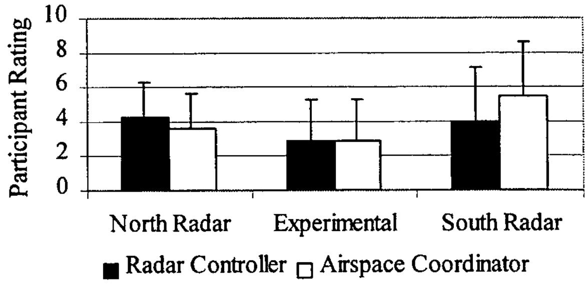

Figure 9. Fix posting data by ATCS role and position.

A secondary trend occurred for automation on the importance of departure airport (Table E-14). ATCSs rated this information more important to have for the LS than the CP function or the DRA function (Figure 10).

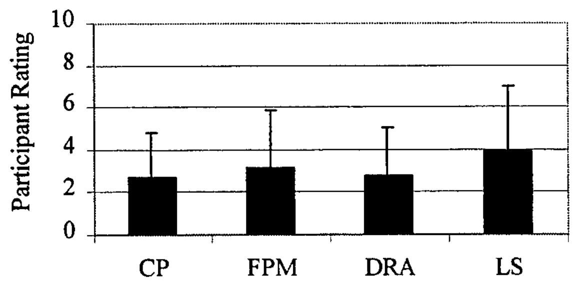

Figure 10. Importance of departure airport by automation.

Primary trends occurred for automation and the ATCS role x automation interaction and a secondary trend occurred for ATCS role for the item assessing importance of arrival airport (Table E-15). For the LS function, ATCSs rated the importance of the arrival airport higher for the Airspace Coordinator than for the R-side ATCS (Figure 11). We did not find differences for the other functions.

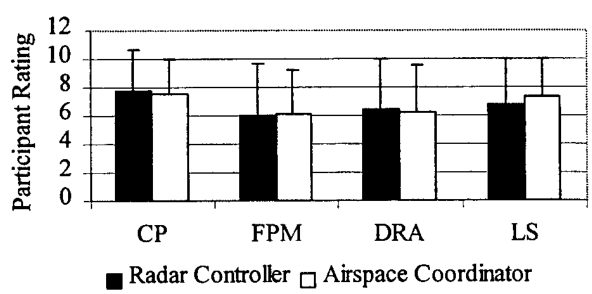

Figure 11. Importance of arrival airport by ATCS role and automation.

For the item assessing importance of flight plan en route airways and fixes, we found a secondary trend for the ATCS role x position interaction (Table E-16). The South R-side ATCSs rated this information as more important for the Airspace Coordinator role than the R-side ATCS role, whereas the North R-side and Experimental ATCSs did not distinguish between these two roles (Figure 12).

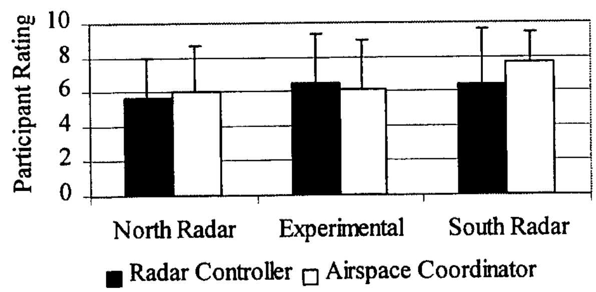

Figure 12. Importance of flight plan en route airways and fixes by ATCS role and position.

We found a secondary trend for position on the importance of aircraft beacon code information (Table E-17). South R-side ATCSs rated this information more important than the Experimental ATCSs but did not differ from the North R-side ATCSs (Figure 13). The North and Experimental ATCSs did not differ.

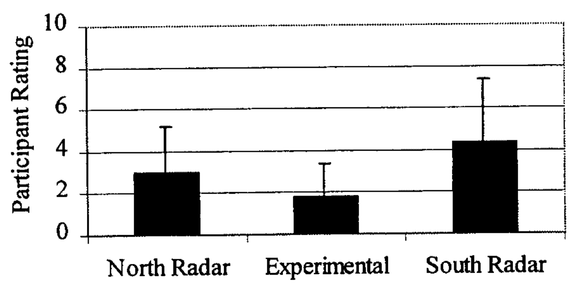

Figure 13. Importance of aircraft beacon code by position.

3.1.2 Radar and Data Block Information

The 2 x 3 x 4 (ATCS role x position x automation) mixed design MANOVA examining the radar and data block information did not show statistically significant effects (Table E-6). We adjusted the alpha to .007 and conducted univariate analyses to examine trends in the data.

We found a secondary trend for the ATCS role x automation interaction on the current location item (Table E-18). When using the LS, ATCSs rated the current location information more important for an Airspace Coordinator (Figure 14). ATCSs did not distinguish between these two roles for the other automation functions.

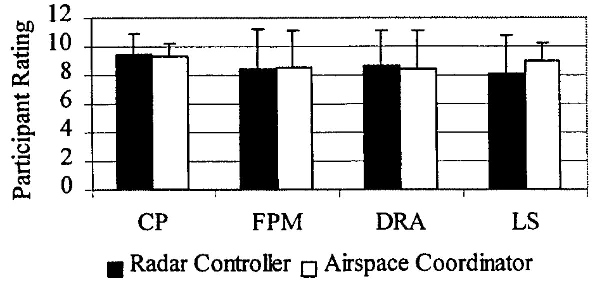

Figure 14. Importance of current location by ATCS role and automation.

The ATCS role x position and automation x position interactions both reached secondary trends for the importance of current heading information (Table E-20). South R-side ATCSs rated this information of more importance for the Airspace Coordinator role than the R-side ATCSs role, whereas the North R-side and Experimental ATCSs did not distinguish differences in importance for these two roles (Figure 15). The North R-side ATCSs rated the importance of current heading information relatively the same for the various automation functions, whereas the Experimental ATCSs rated this information least important for the DRA relative to the CP, FPM, and LS functions (Figure 16). The South R-side ATCSs rated this information least important for the CP relative to the other functions.

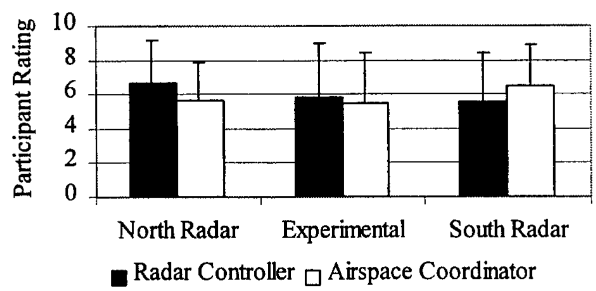

Figure 15. Importance of current heading by ATCS role and position.

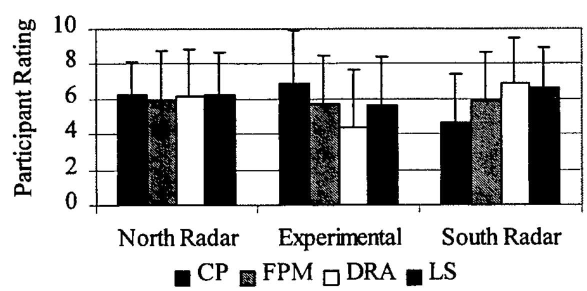

Figure 16. Importance of current heading by automation and position.

A primary trend for automation and a secondary trend for the ATCS role x automation interaction occurred for the importance of current airspeed (Table E-21). The ATCS role qualified the effect of automation, and we focus on this. For the CP function, ATCSs rated the current airspeed information more important for the R-side ATCS role (Figure 17). ATCSs did not differ in their importance ratings along the other automation functions.

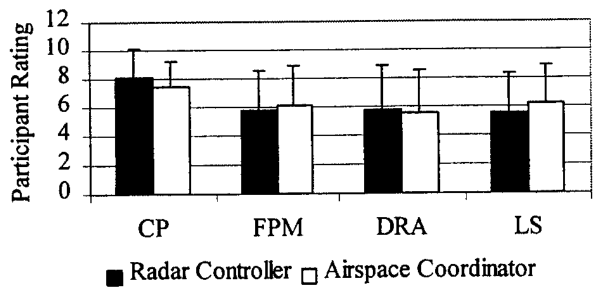

Figure 17. Importance of current airspeed by ATCS role and automation.

Secondary trends occurred for automation and the automation x position interaction for the importance of interim altitude information (Table E-22). We focus on the interaction because it qualified the effect of automation. The North R-side ATCSs did not rate the importance of interim altitude information different depending on the automation function (Figure 18). However, the Experimental ATCSs indicated that interim altitude information would be most important for the CP function compared to either the DRA or LS functions. Their ratings for the importance of this item did not differ between the CP or FPM functions. South R-side ATCSs indicated that the importance of interim altitude information was lower for the LS function than the CP function or the DRA function. Their ratings for this item for either the LS or the FPM did not differ.

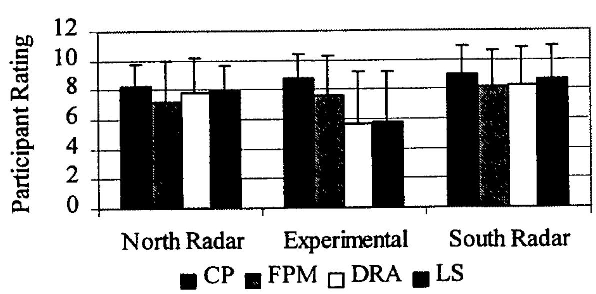

Figure 18. Importance of interim altitude by automation and position.

For the importance of altitude change indicator (level, climb, or descent), we found a secondary trend for the ATCS role x automation interaction (Table E-23). Further analyses showed that ATCSs felt it was more important for the R-side ATCS role when they would use the CP function compared to the DRA or LS function (Figure 19). Their ratings did not differ between the CP and the FPM. They did not differ for the various automation functions when used by the Airspace Coordinator.

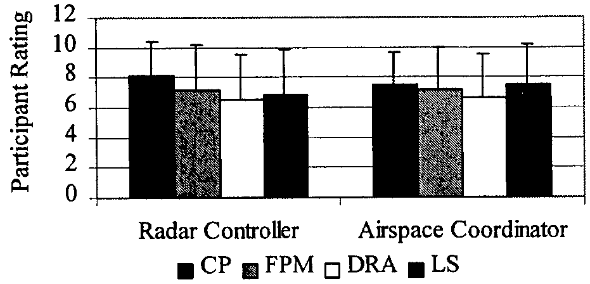

Figure 19. Importance of altitude change indicator (level, climb, descent) by ATCS role and automation.

For the item assessing the importance of aircraft handoff status, we found a secondary trend for the ATCS role x automation interaction (Table E-24). For the CP function, ATCSs indicated that it would be more important for the R-side ATCS role than the Airspace Coordinator role (Figure 20). They did not differentiate the importance of this information for the R-side ATCS versus the Airspace Coordinator roles for the other automation functions.

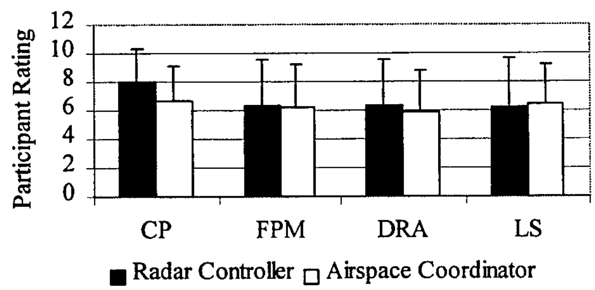

Figure 20. Importance of aircraft handoff status by ATCS role and automation.

3.1.3 Assigned Control Actions

We conducted a 2 x 3 x 4 (ATCS role x position x automation) mixed design MANOVA for the assigned control action items. The ATCS role x automation interaction was significant [$\Lambda = .46$, $F(9,19) = 2.46, p < .05$, Table E-7]. We conducted follow-up ANOVAs and adjusted the alpha to .017.

We found a primary trend for the ATCS role x automation interaction for the importance of assigned heading (Table E-26). The Experimental ATCSs rated this information more important for the R-side ATCS role than for the Airspace Coordinator role (Figure 21). The North and South R-side ATCSs did not rate the importance of this item different for the R-side ATCS or the Airspace Coordinator.

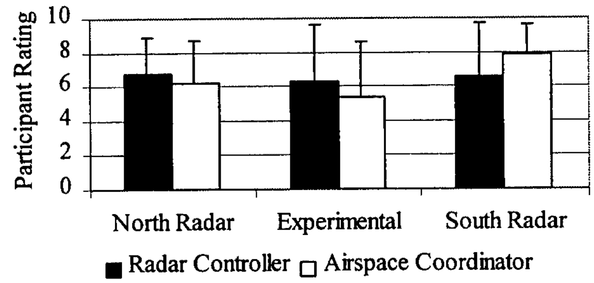

Figure 21. Importance of assigned heading by ATCS role and position.

3.1.4 Map Display Data

We conducted a 2 x 3 x 4 (ATCS role x position x automation) mixed design MANOVA for the items comprising the map display data information. We did not find statistically significant results at the multivariate level (Table E-8). We conducted ANOVAs to examine any trends in the data and adjusted the alpha to .013.

We found a primary trend for the ATCS role x automation interaction for the importance of sector boundaries information (Table E-28). ATCSs rated this information more important for the R-side ATCS role when using the CP function (Figure 22). ATCSs did not rate the importance of this information differently for the R-side ATCS or Airspace Coordinator using any of the other automation functions.

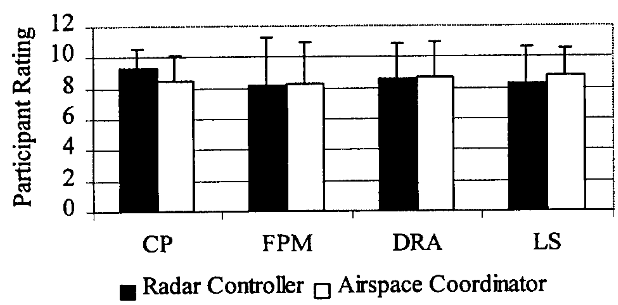

Figure 22. Importance of sector boundaries by ATCS role and automation.

For the importance of Special Use Airspace (SUA) boundaries, we found a primary trend for the ATCS role x automation interaction (Table E-29). When using the CP function, ATCSs felt this information would be more important for the R-side ATCS role. In contrast, they felt that when using the LS, this information would be more important for the Airspace Coordinator (Figure 23). There were no differences between importance ratings for the R-side ATCS and Airspace Coordinator roles for either the FPM or the DRA functions.

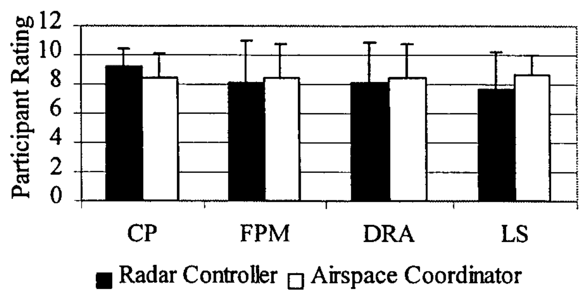

Figure 23. Importance of SUA boundaries by ATCS role and automation.

For the importance of heavy weather location information, we found primary trends for automation and the ATCS role x automation interaction and a secondary trend for ATCS role (Table E-30). We focus on the interaction because it qualified the main effects. The effect of ATCS role was significant within the FPM and LS functions but not for the CP and DRA functions. ATCSs rated this information more important for Airspace Coordinators when using either the FPM or the LS (Figure 24).

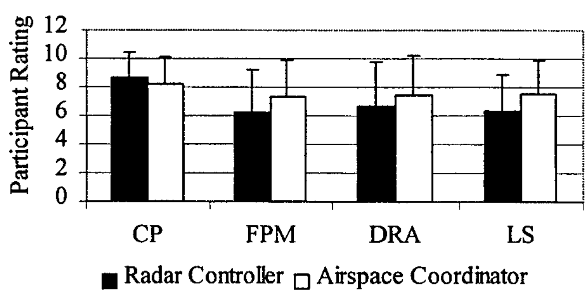

Figure 24. Importance of heavy weather location by ATCS role and automation.

We found a secondary trend for the ATCS role x position interaction for the importance of VORs (Table E-31). The effect of position was significant for the Airspace Coordinator role. South R-side ATCSs rated this information more important than North R-side ATCSs for the Airspace Coordinator role (Figure 25). The South and Experimental ATCSs and the Experimental and North R-side ATCSs did not differ.

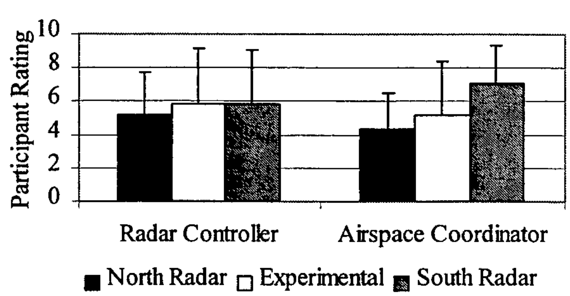

Figure 25. Importance of VORs by ATCS role and position.

3.2 Trial Planning Questions

We had several items comprise the trial planning questions for the CP, DRA, and LS functions. We conducted a 2 x 3 x 3 (ATCS role x automation x position) mixed MANOVA. We did not find statistically significant results at the multivariate level (Table F-2). We conducted univariate analyses to examine trends in the data and adjusted the alpha to .008. We provide means, *SDs*, MANOVA, and ANOVA tables in Appendix F.

We found a secondary trend for ATCS role for the importance of conflict status (Table F-3). ATCSs rated this as more important for the Airspace Coordinator role than the R-side ATCS role (Figure 26).

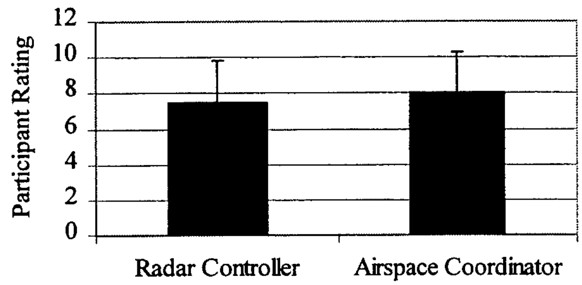

Figure 26. Importance of conflict status by ATCS role.

For the importance of aircraft trajectory, we found secondary trends for ATCS role and automation (Table F-4). ATCSs rated this information as more important for the Airspace Coordinator role (Figure 27). ATCS rated this information least important for the CP function as compared to either the DRA or LS functions (Figure 27).

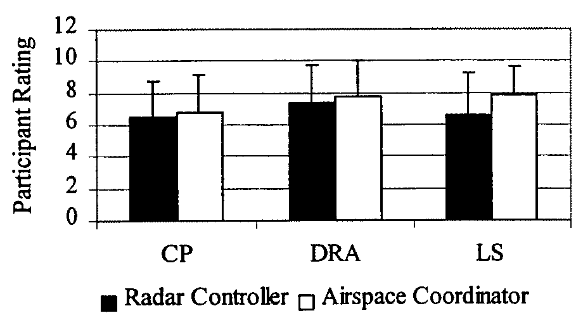

Figure 27. Importance of aircraft trajectory by ATCS role and automation.

For the importance of displaying aircraft trajectories and LOS point with other aircraft if there is a conflict, we found a secondary trend for ATCS role (Table F-6). ATCSs indicated that this information would be more important for the Airspace Coordinator (Figure 28).

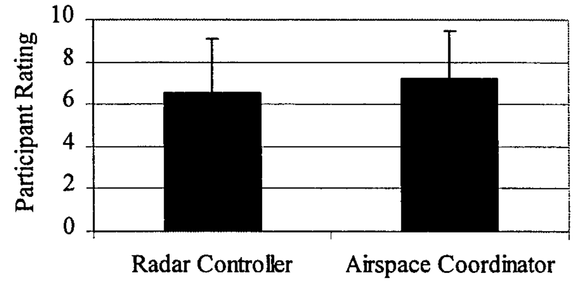

Figure 28. Importance of aircraft trajectories and LOS point with other aircraft in conflict by ATCS role.

3.3 Conflict Probe, Conflict Resolution, and Trial Planning Questions Only

We had several items for the CP questions only that examined the importance of conflict alert indicator, aircraft trajectory and LOS point, time until LOS, closest-point-of-approach for aircraft, SUA, and weather conflict probe data. Aircraft, SUA, and weather conflict probes comprised the three levels of the IV probe type that we created. We conducted a 2 x 3 x 3 (ATCS role x probe type x position) mixed MANOVA. We found a significant effect for probe type [$\Lambda = .38$, $F(8,20) = 4.06$, $p < .01$, Table G-2]. We conducted follow-up univariate analyses and adjusted the alpha to .013. We provide means, *SDs*, MANOVA, and ANOVA tables in Appendix G.

We found a significant main effect for probe type [$F(2,54) = 15.08$, $p < .0001$] and a primary trend for the ATCS role x probe type interaction for the importance of conflict alert indicator (Table G-3). The importance of this item was lowest for the weather conflict probe than either the aircraft or SUA conflict probe, whereas the aircraft and SUA conflict probes did not differ statistically (Figure 29). The effect of ATCS role qualified this main effect. The effect of ATCS role was significant for aircraft conflict probe but not for either the SUA or weather conflict probes. ATCSs rated the aircraft conflict alert indicator as more important for the R-side ATCS role when using the aircraft conflict alert indicator information (Figure 29).

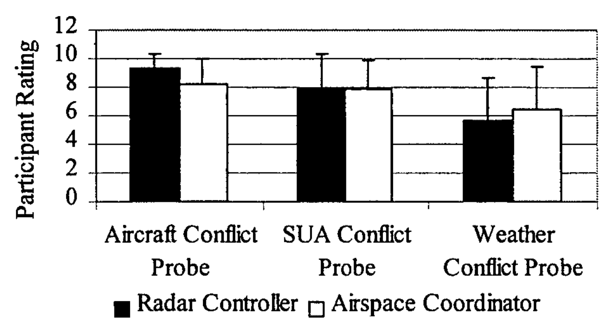

Figure 29. Importance of aircraft conflict alert indicator by ATCS role and probe type.

For the importance of aircraft trajectory and LOS point, we found a main effect for probe type [$F(2,54) = 13.24, p < .0001$] and a secondary trend for probe type x position (Table G-4). ATCSs rated this information as more important for the aircraft conflict probe data than for the weather conflict probe data, whereas the aircraft and SUA conflict probe data and the SUA and weather conflict probe data were not statistically different (Figure 30). The interaction showed that the type of probe was significant for the North R-side and Experimental ATCSs but not for the South R-side ATCSs. The North R-side ATCSs rated the aircraft trajectory and LOS point information least important for the weather conflict probe data, and there were no differences between the aircraft and SUA conflict probe data. In contrast, the Experimental ATCSs rated this information as less important than the aircraft probe data but not different than the SUA conflict probe data.

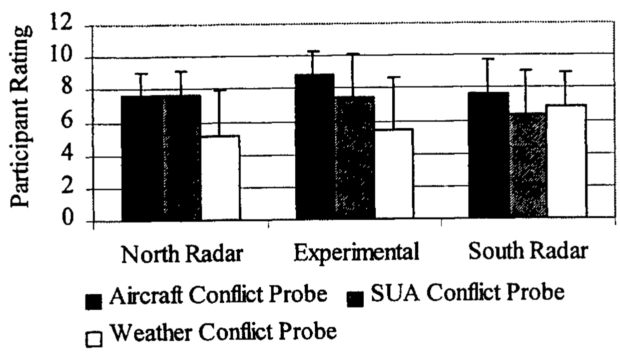

Figure 30. Importance of aircraft trajectory and LOS point by probe type and position.

We found a significant main effect for probe type for the importance of time until LOS [$F(2,54) = 15.46, p < .0001$, Table G-5]. We also found secondary trends for ATCS role and the probe type x position interaction. Tukey post hoc tests showed that ATCSs considered this information to be more important for aircraft conflict probe data than for weather probe data but that aircraft and SUA conflict probe data or SUA and weather conflict probe data were not statistically different. The position of the ATCS qualified this effect. The effect of probe type was significant for the North R-side and Experimental ATCSs, but not for the South R-side ATCSs (Figure 31). North R-side ATCSs rated the weather conflict probe data significantly less important than either the aircraft or SUA conflict probe data, whereas the latter two did not differ statistically. Experimental ATCSs rated the importance of time until LOS as most important for the aircraft conflict probe data, but they did not differentiate the importance between SUA and weather conflict probe data (Figure 32).

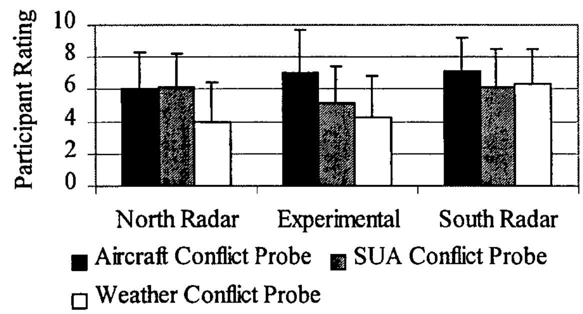

Figure 31. Importance of time until LOS by probe type and position.

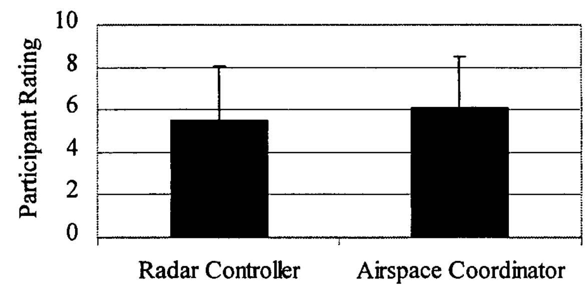

Figure 32. Importance of time until LOS by ATCS role.

For the item assessing the importance of the closest-point-of-approach, we found a secondary trend for probe type (Table G-6). ATCSs rated this information as the least important for the weather conflict probe data (Figure 33).

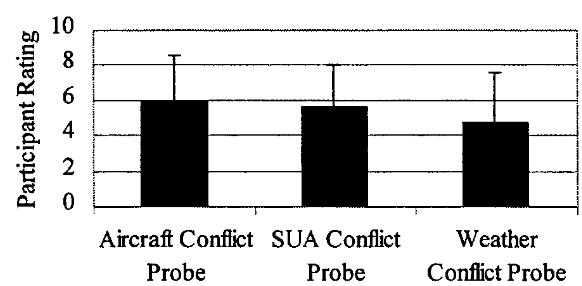

Figure 33. Importance of closest-point-of-approach by probe type.

Conflict Probe, Resolution Advisory, and Trial Planning Questions Only

The remaining items asking about the CP function comprised conflict resolution advisory data. We conducted a 2 x 3 (ATCS role x position) mixed MANOVA. We did not find statistically significant results at the multivariate level (Table H-2, Appendix H). We conducted univariate analyses to examine trends in the data and adjusted the alpha to .017. We did not find trends in the data.

3.5 Flight Path Monitor Questions Only

The importance of fight path deviation alert indicator for involved aircraft, aircraft deviation trajectory, aircraft planned route, extent of lateral and/or altitude deviation, and lateral and/or altitude deviation criteria for alert comprised the flight path deviation data for only the FPM function. We conducted a 2 x 3 (ATCS role x position) mixed MANOVA on these items. We did not find statistically significant results at the multivariate level nor did we find trends at the univariate level of analysis (Table I-2, Appendix I).

3.6 Direct Routing Advisory Questions Only

Primary DRA control action for each aircraft, alternate DRA control action for each aircraft, aircraft trajectory under advisory route, actual time and distance savings with advisory route, and time and distance savings criteria for aircraft identification comprised the DRA data items. We conducted a 2 x 3 (ATCS role x position) mixed MANOVA on the above items. We did not find statistically significant results at the multivariate level of analysis, nor did we find trends in the data at the univariate level of analysis (Table J-2, Appendix J).

3.7 Load Smoother Questions Only

The importance of the primary LS advisory control action for each aircraft, alternate LS advisory control action for each aircraft, aircraft trajectory under advisory route, and "hot spots" under advisory route for specific times comprised the LS advisory data specific only to the LS. We conducted a 2 x 3 (ATCS role x position) mixed MANOVA on these items. We found an effect for ATCS role [$F(4,24) = 3.67, p < .05$, Table K-2, Appendix K]. We conducted follow-up ANOVAs and adjusted the alpha to .013.

We found a main effect for the ATCS role for the importance of primary and alternate LS advisory control action for each aircraft, aircraft trajectory under advisory route information, and "hot spots" under advisory route for specific times information [$F(1,27) = 11.26, p < .01$, $F(1,27) = 9.06, p < .01$; $F(1,27) = 11.23, p < 01$; $F(1,27) = 14.46, p < .001$, Tables K-3, K-4, and K-5, respectively]. ATCSs rated these as more important for the Airspace Coordinator than for the R-side ATCS role (Figure 34).

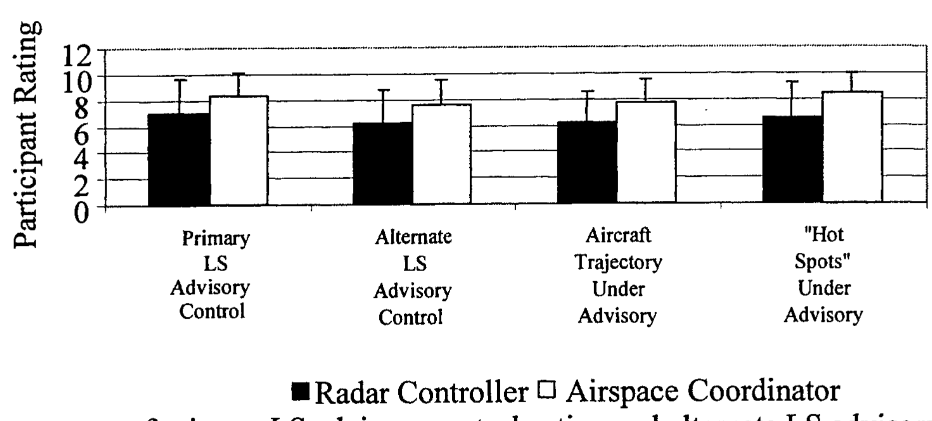

Figure 34. Importance of primary LS advisory control action and alternate LS advisory control action for each aircraft, aircraft trajectory under advisory route, and "hot spots" under advisory route by ATCS role.

Although ATCSs rated most types of data important, a pattern emerged that distinguished the types of information and data ATCSs needed when using the CP functions in contrast to the LS function. Results seem to indicate that ATCSs perceived the CP to be a more important automation function for ATCSs working in the R-side role and the LS as more important for the Airspace Coordinator role. However, this is not to say that our participant ATCSs believed that only the R-side should use the CP, whereas only the Airspace Coordinator should use the LS. Instead, the findings point toward differences in the types of data/information that ATCSs viewed as important for a given function when used by a given position. When ATCSs use the CP as an R-side, the R-side needs detailed information on the aircraft in conflict. In this instance, the R-side is in tactical control of the aircraft, and, if any aircraft have potential problems with each other, the R-side needs to know exactly which aircraft they are and needs to make the appropriate changes to routes or altitudes. R-side ATCSs frequently use the CID for entries. This explains the higher importance this item has for the R-side compared to the Airspace Coordinator. In contrast, the Airspace Coordinator is not in tactical control of aircraft but assists multiple sectors by finding more expedient, conflict free routes for aircraft. He or she does not deal with tactical control issues and can focus on those aircraft he or she designates as important.

The LS automation function contrasts nicely with the CP. We see a pattern develop that is mostly opposite to that of the CP. ATCSs seem to view the LS as a function used predominantly by the Airspace Coordinator. Because of this, they rate more detailed information such as where the hot spots are along with detailed information about the aircraft in those hot spots as important. This relates to the function of the Airspace Coordinator. The Airspace Coordinator oversees a larger volume of airspace than just a sector wants to move aircraft as efficiently as possible, conflict free through that airspace. He or she needs to know where potential problem areas are and then which aircraft contribute to those problem areas. He or she can then make the necessary calls to R-side ATCSs to change flight plans and alleviate those hot spots. The R-side functions as a tactical decision maker who needs a general idea of where the hot spots are from an LS but then uses the radar display to gain more information while tactically controlling aircraft. In addition, the LS may indicate relatively high traffic areas, without actually having conflicts. The R-side ATCSs interest is in aircraft with potential conflicts, thus the CP is a more vital automation function for them.

We also asked ATCSs about FPM and DRA functions. ATCSs seemed to view these functions as moderately important and placed the various data/information needed for them around the middle of the scale.

We gained some information about the importance of various data/information that would need to be available in future automation functions. However, it is important to note that the ATCSs in our experiment did not actually use any of these automation functions during the experiment nor did they see these functions in use. We briefed them on each automation function before experimental runs and then included information about each function on subsequent questionnaires as a reminder. Because the ATCSs did not actually get to use or explore these functions in a simulation environment, they had to rely on their ability to project how these functions would really work. This may have limited their insight into how important the various data/information inquired about was to a particular function. It is important in future studies to

give ATCSs access to these automation functions and then inquire about the usefulness of particular pieces of information. However, the information we obtained gives us a starting point to what may be important for automation functions and a line of research to pursue.

Another implication of our findings is that when providing ATCSs with automation tools, the format and amount of information displayed needs to depend on the ATCS position. Therefore, if the same automation tool may be useful at different ATCS positions, the resulting Computer-Human Interface may differ. A good example of how dramatically different these interfaces might be is the Traffic Management Advisor (TMA). At the TMU, TMA displays timelines and allows Traffic Management Coordinators to look at graphical displays of sector loading. At the sector, there is a TMA list on the DSR that only shows aircraft ID, time over a fix, and expected delay the ATCS needs to absorb. The FAA envisions a number of DSTs (e.g., TMA, Direct To, and URET) at the sectors. To prevent information overload, integration of the information of these tools becomes essential. Our study has shown that ATCSs feel we should present this information in a format that best fits the duties of a particular ATC position. In research studies that will incorporate planned automation tools, we need to address how to present the information that these tools produce in a way that best supports ATCSs when working at a particular position.

4. Relevance to Air Traffic Services

The introduction of decision support automation for the D-side and the R-side ATCS will change the roles and responsibilities in the ATC sector team. We see differences between R-side ATCSs and an airspace coordinator. For a more strategic position, the information needs and format of information display may change. When providing ATCSs with information that can help them control traffic more efficiently, it is important to consider that the information format that is useful to a R-side ATCS may not be useful to a more strategic position.

Some of the information that the new or planned automation functions will bring to the sector was initially available to the TMU. Information used at the TMU is less time critical because that unit is not immediately responsible for radar separation. Therefore, lists of information about aircraft are acceptable. At the sector, however, ATCSs are responsible for radar separation and prefer to have a display of information that is free of clutter.

References

Barrow, D. (2000). *CINCAT market assessment report (D8.2)*. Document CINCAT/WP8/D8.2/1.0. Christchurch, UK: NATS ATMDC.

Couluris, G. J. (2000). *Detailed description for CE6 en route trajectory negotiation* (NASA Tech. Note 3 NAS2-98005 RTO-41). Moffet Field, CA: NASA.

Federal Aviation Administration. (1998). Air Traffic Control (DOT/FAA/Order 7110.65L). Washington, DC: Author.

Latron, P., McGregor, R., Geissel, M., Wassmer, E., & Marsden, E. (1997). *En-route multi-sector planning procedures* (DOC 97-70-15). Bruxelles, Belgium: Eurocontrol.

Leiden, K. J., & Green, S. M. (2000). Trajectory orientation: A technology-enabled concept requiring a shift in controller roles and responsibilities. *3rd USA/Europe Air Traffic Management R&D Seminar*. Napoli, Italy.

Louden, G., Lawson, N., Thompson, K., & Viets, K. (1999). *Scenario description for validation of the 2005 en route operational concept* (WN 99W0000004). McLean, VA: MITRE Center for Advanced Aviation System Development.

McNally, D. (2000, May). Direct-to controller tool. Slide presentation at the *IAIPT J12 JRPD Human Factors in Acquisition Programs Meeting*. Washington, DC.

Meckiff, C., Chone, R., & Nicolaon, J. P. (1998). *The tactical load smoother for multi-sector planning*. Paper presented at the meeting of the 2nd USA/Europe Air Traffic Management R&D Seminar, Orlando, FL.

Micro Analysis & Design, Inc., & System Resources Corporation. (2000). *Research task order 34: Intersector planning. En route controller roles and responsibilities final report.* Moffet Field, CA: NASA Ames Research Center.

Mogford, R. H., Murphy, E. D., Roske-Hostrand, R. J. , Yastrop, G., & Guttman, J. (1994). *Research techniques for documenting cognitive processes in Air Traffic Control: Sector complexity and decision making* (DOT/FAA/CT-TN94/3). Atlantic City International Airport, NJ: Federal Aviation Administration.

Nicolaon, J. P., De Jonge, H. W. G., Maddock, R. O., Cazard, B., & McGregor, R. (1997a). *PD/3 operational scenarios document* (Volume I) (DOC 97-70-08). Bruxelles, Belgium: Eurocontrol.

Nicolaon, J. P., De Jonge, H. W. G., Maddock, R. O., Cazard, B., & McGregor, R. (1997b). *PD/3 operational scenarios document* (Volume II) (DOC 97-70-08). Bruxelles, Belgium: Eurocontrol.

Office of Air Traffic System Development. (1997). *AUA program master plan (Volume 2): Automation strategic planning*. Washington, DC: Federal Aviation Administration.

Thompson, K. H., Hollenberger, J. M., & Taber, N. J. (1999). *Laboratory validation results of proposed en route NAS midterm responsibilities and capabilities* (MTR 99W0000105). McLean, VA: MITRE Center for Advanced Aviation System Development.

Van Gool, M., & Schroeter, H. (1999). *Programme for harmonised ATM research in eurocontrol (PHARE) final report* (DOC 99-70-09). Bruxelles, Belgium: Eurocontrol.

Vivona, R. A., Ballin, M. G., Green, S. M., Bach, R. E., & McNally, B. D. (1996). *A system concept for facilitating user preferences in en-route airspace* (NASA TM-4763). Washington, DC: National Aeronautics and Space Administration.

Willems, B. F., & Truitt, T. R. (1999). *Implications of reduced involvement in en-route Air Traffic Control* (DOT/FAA/CT-TN99/22). Atlantic City International Airport, NJ: William J. Hughes Technical Center.

Acronyms

ANOVA	Analysis of Variance
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATCS	Air Traffic Control Specialist
CAASD	Center for Advanced Aviation System Development
CID	Computer Identification
CP	Conflict Probe, Conflict Resolution, and Trial Flight Planning
D-side	Data
DRA	Direct Routing Advisory
DSR	Display System Replacement
DST	Decision Support Tool
DV	Dependent Variable
ERP	Engineering Research Psychologist
FAA	Federal Aviation Administration
4D	Four Dimensional
FPM	Flight Path Monitor
FPS	Flight Progress Strip
IRQ	Information Requirements Questionnaire
IV	Independent Variables
LOS	Losses of Separation
LS	Load Smoother
MANOVA	Multivariate Analysis of Variance
MSP	Multi-sector Planner
NAS	National Airspace System
NASA	National Aeronautics and Space Agency
R-side	Radar
SA	Situation Awareness
SD	Standard Deviation
SUA	Special Use Airspace
TMA	Traffic Management Advisor
TMU	Traffic Management Unit
URET	User Request Evaluation Tool

Appendix A

ATCS Roles and Responsibilities

ATCS Roles and Responsibilities

Radar	Radar Associate (RA)	Flight Data (D)	Non-Radar
Ensure separation	Ensure separation	Operate interphones	Ensure separation
Initiate control instructions	Initiate control instructions	Assist the RA-position in managing flight progress strips	Initiate control instructions
Monitor and operate radios	Operate interphones	Receive/process and distribute flight progress strips	Monitor and operate radios
Accept and initiate automated handoffs	Accept and initiate automated handoffs, and ensure radar position is made aware of the actions	Ensure flight data processing equipment is operational	Accept and initiate transfer of control, communications, and flight data
Assist the RA position with non-automated handoff actions when needed	Assist the R-side position by accepting or initiating automated handoffs which are necessary for the continued smooth operation of the sector, and ensure that the R-side is made immediately aware of any action taken	Request/receive and disseminate weather, NOTAM's, NAS status, traffic management, and Special Use Airspace status messages	Ensure computer entries are completed on instructions or clearances issued or received
Assist the RA position in coordination when needed	Coordinate including point outs	Manually prepare flight progress strips when automation systems are not available	Ensure strip marking is completed on instructions or clearances issued or received
Scan radar display. Correlate with flight progress strip information	Monitor radios when not performing higher priority duties	Enter flight data into computer	Facilities utilizing nonradar positions may modify the standards contained in the radar associate
Ensure computer entries are completed on instructions or clearances you issue or receive	Scan Flight Progress Strips. Correlate with radar data.	Forward flight data via computer	
Ensure strip marking is completed on instructions or clearances you issue or receive	Manage Flight Progress Strips.	Assist facility/sector in meeting situation objectives	
Adjust equipment at R-side to be usable by all members of the team	Ensure computer entries are completed on instructions issued or received by the R-side when aware of those instructions.		
The R-side shall not be responsible for G/G communications when precluded by VSCS split functionality	Ensure strip marking is completed on instruction issued or received byt the R-side when aware of them.		
	Adjust equipment at RA-position to be usable by all members of the team		

Appendix B

Information Requirements Questionnaire

Information Requirements Questionnaire

Information Requirements for Future Automation Functions

Instructions:

The following questions ask you to consider future automation functions that could be developed to assist controllers. For each automation function (or group of related functions), indicate how important the flight data, radar, and other information would be for controllers to know as they use the proposed automation function. Mark a number based upon the Importance Scale below for both the Radar and Airspace Coordinator positions separately.

Importance Scale

Not Important	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	**Very Important**

Information Requirements Questionnaire

Aircraft, SUA, and Weather Conflict Probe, Resolution Advisory, and Trial Planning Functions

Importance Scale

Not Important	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	Very Important

Flight Data	Radar Controller	Airspace Coordinator
Aircraft Callsign	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Type and Equipage	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Computer ID	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Sector Control Designator	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Fix Posting Data	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Departure Airport	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Arrival Airport	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Flight Plan En Route Airways and Fixes	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Beacon Code	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Radar and Data Block	**Radar Controller**	**Airspace Coordinator**
Current Location	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Heading	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Airspeed	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Interim Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Altitude Change Indicator (level, climb, or descent)	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Handoff Status	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Control Actions	**Radar Controller**	**Airspace Coordinator**
Assigned Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Heading	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Airspeed	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Map Display Data	**Radar Controller**	**Airspace Coordinator**
Sector Boundaries	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Special Use Airspace Boundaries	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Heavy Weather Location	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
VORs	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩

Aircraft, SUA, and Weather Conflict Probe, Resolution Advisory, and Trial Planning Functions **(Continued)**

Importance Scale

Not Important	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	Very Important

Aircraft Conflict Probe Data	Radar Controller	Airspace Coordinator
Aircraft Conflict Alert Indicator for Involved Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Conflicting Aircraft Callsign(s)	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Trajectory & LOS Point with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Time until LOS with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Closest-Point-of-Approach with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
SUA Conflict Probe Data	**Radar Controller**	**Airspace Coordinator**
SUA Conflict Alert Indicator for Involved Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Trajectory & LOS Point with SUA	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Time until LOS with SUA	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Closest-Point-of-Approach with SUA	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Weather Conflict Probe Data	**Radar Controller**	**Airspace Coordinator**
Weather Conflict Alert Indicator for Involved Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Trajectory & LOS Point with Weather	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Time until LOS with Weather	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Closest-Point-of-Approach with Weather	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Conflict Resolution Advisory Data	**Radar Controller**	**Airspace Coordinator**
Primary Resolution Advisory Control Action for each Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Alternate Resolution Advisory Control Action for each Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Trajectory under Resolution Advisory	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Trial Planning Data	**Radar Controller**	**Airspace Coordinator**
Trial Plan Conflict Status (conflict or clear)	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Trajectory under Trial Plan	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Conflicting Aircraft Callsign(s)	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Aircraft Trajectories & LOS Point with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Time until LOS with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Closest-Point-of-Approach with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩

Is there any additional information that would be useful to use this group of functions for its intended purposes?

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Information Requirements Questionnaire

Flight Path Monitor Function

Flight Data	Radar Controller	Airspace Coordinator
Aircraft Callsign	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Type and Equipage	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Computer ID	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Sector Control Designator	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Fix Posting Data	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Departure Airport	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Arrival Airport	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Flight Plan En Route Airways and Fixes	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Beacon Code	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Radar and Data Block	**Radar Controller**	**Airspace Coordinator**
Current Location	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Heading	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Airspeed	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Interim Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Altitude Change Indicator (level, climb, or descent)	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Handoff Status	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Control Actions	**Radar Controller**	**Airspace Coordinator**
Assigned Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Heading	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Airspeed	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Map Display Data	**Radar Controller**	**Airspace Coordinator**
Sector Boundaries	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Special Use Airspace Boundaries	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Heavy Weather Location	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
VORs	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Flight Path Deviation Data	**Radar Controller**	**Airspace Coordinator**
Flight Path Deviation Alert Indicator for Involved Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Deviation Trajectory	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Planned Route	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Extent of Lateral and/or Altitude Deviation	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Lateral and/or Altitude Deviation Criteria for Alert	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩

Is there any additional information that would be useful to use this function for its intended purposes?

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Information Requirements Questionnaire

Direct Routing Advisory and Trial Planning Function

Importance Scale

Not Important ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ **Very Important**

Flight Data	Radar Controller	Airspace Coordinator
Aircraft Callsign	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Type and Equipage	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Computer ID	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Sector Control Designator	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Fix Posting Data	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Departure Airport	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Arrival Airport	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Flight Plan En Route Airways and Fixes	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Beacon Code	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Radar and Data Block	**Radar Controller**	**Airspace Coordinator**
Current Location	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Heading	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Airspeed	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Interim Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Altitude Change Indicator (level, climb, or descent)	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Handoff Status	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Control Actions	**Radar Controller**	**Airspace Coordinator**
Assigned Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Heading	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Airspeed	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Map Display Data	**Radar Controller**	**Airspace Coordinator**
Sector Boundaries	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Special Use Airspace Boundaries	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Heavy Weather Location	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
VORs	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩

Direct Routing Advisory and Trial Planning Function (Continued)

Importance Scale

Not Important	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	Very Important

Direct Routing Advisory Data	Radar Controller	Airspace Coordinator
Primary Direct Routing Advisory Control Action for each Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Alternate Direct Routing Advisory Control Action for each Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Trajectory under Advisory Route	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Actual Time and Distance Savings with Advisory Route	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Time and Distance Savings Criteria for Aircraft Identification	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Trial Planning Data	**Radar Controller**	**Airspace Coordinator**
Trial Plan Conflict Status (conflict or clear)	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Trajectory under Trial Plan	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Conflicting Aircraft Callsign(s)	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Aircraft Trajectories & LOS Point with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Time until LOS with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Closest-Point-of-Approach with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩

Is there any additional information that would be useful to use this group of functions for its intended purposes?

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Information Requirements Questionnaire

Load Smoother Advisory and Trial Planning Functions

Importance Scale

Not Important	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	Very Important

Flight Data	Radar Controller	Airspace Coordinator
Aircraft Callsign	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Type and Equipage	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Computer ID	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Sector Control Designator	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Fix Posting Data	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Departure Airport	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Arrival Airport	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Flight Plan En Route Airways and Fixes	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Beacon Code	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Radar and Data Block	**Radar Controller**	**Airspace Coordinator**
Current Location	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Heading	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Current Airspeed	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Interim Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Altitude Change Indicator (level, climb, or descent)	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Handoff Status	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Control Actions	**Radar Controller**	**Airspace Coordinator**
Assigned Altitude	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Heading	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Assigned Airspeed	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Map Display Data	**Radar Controller**	**Airspace Coordinator**
Sector Boundaries	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Special Use Airspace Boundaries	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Heavy Weather Location	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
VORs	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩

Load Smoother Advisory and Trial Planning Functions (Continued)

Importance Scale

Not Important	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	Very Important

Load Smoother Advisory Data	Radar Controller	Airspace Coordinator
Primary Load Smoother Advisory Control Action for each Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Alternate Load Smoother Advisory Control Action for each Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Trajectory under Advisory Route	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
"Hot Spots" under Advisory Route for Specific Times	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Trial Planning Data	**Radar Controller**	**Airspace Coordinator**
Trial Plan Conflict Status (conflict or clear)	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
Aircraft Trajectory under Trial Plan	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
"Hot Spots" under Trial Plan for Specific Times	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Conflicting Aircraft Callsign(s)	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Aircraft Trajectories & LOS Point with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Time until LOS with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩
If Conflict, Closest-Point-of-Approach with Other Aircraft	①②③④⑤⑥⑦⑧⑨⑩	①②③④⑤⑥⑦⑧⑨⑩

Is there any additional information that would be useful to use this function for its intended purposes?

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Appendix C

Informed Consent Form

Informed Consent Form

I, ____________________________, understand that the Federal Aviation Administration sponsors and Ben Willems direct this study, entitled the "Study of an ATC Baseline for the Evaluation of Team-configurations" (SABET). SABET will investigate the effect of traffic load, the use of Decision Support Tools, and alternative team configurations on controller performance and behavior.

Nature and Purpose

I will volunteer as a participant in the project above. The purpose is to explore active controllers' use of different levels of automation in different team configurations. The time requirement for this experiment is six days. I will travel on Monday and Friday. On the two test days of the experiment, I will participate in 4 practice and 8 experiment simulations of 45 minutes each.

Experimental Procedures

If the research team assigns me to the position that uses most automation, the movements of my eyes will be monitored during the simulations. A small camera mounted on a headband will monitor my eye movements. An invisible beam of infrared light will illuminate my eye.

The simulations will mimic future operational air traffic conditions. I will interact with simulation pilots and control simulated air traffic like I would normally do in the field.

Discomforts and Risks

The device that monitors the eye movements may cause some discomfort. The skin area under the headband that supports the device may show some redness after wearing the device for the duration of a simulation. The intensity of the infrared beam that illuminates the eye is about one thirtieth of the intensity expected while walking outside on a sunny day and should not cause any discomfort or risk to my health.

Benefits

I understand that the only direct benefit to me is to participate in research in Atlantic City, NJ.

The benefit derived from the results of this experiment for controllers may include a better understanding of why operational errors occur, which could lead to new ways to assist ATC students.

Informed Consent Form

Participant's Responsibilities

During the experiment, it will be my responsibility to control the simulated air traffic as if I was controlling traffic at my home facility. I will answer any questions asked during the experiment to the best of my abilities. I will not discuss the content of the experiment with anyone until the completion of the experiment.

Participant's Assurances

I understand that my participation in this study is voluntary. Ben Willems has adequately answered any questions I have about this study, my participation, and the procedures involved. I understand that Ben Willems will be available to answer any questions concerning procedures throughout this study. I understand that if new findings develop during the course of this research that may relate to my decision to continue to participation, I will be informed.

I have not given up any of my legal rights or released any individual or institution from liability for negligence.

I understand that records of this study are strictly confidential, and that I will not be identifiable by name or description in any reports or publications about this study. Photographs and audio and video recordings are for use within the Research and Development Human Factors Laboratory only. Any of the materials that may identify me as a participant cannot be used for purposes other than internal Research Development and Human Factors Laboratory without my written permission.

I understand I can withdraw from the study at any time without penalty or loss of benefits to which I may be entitled. I also understand that the researcher of this study may terminate my participation if he feels this to be in my best interest.

If I have questions about this study or need to report any adverse effects from the research procedures, I will contact Ben Willems at (609) 485-4191 during Monday through Friday or at (609)-404-1650 in the evening or on weekends.

I may also contact Dr. Earl Stein (609) 485-6389, the Air Traffic Human Factors Technical Lead at any time with questions or concerns.

I have read this consent document. I understand its contents, and I freely consent to participate in this study under the conditions described. I have received a copy of this consent form.

Research Participant: ______________________ Date: __________

Investigator: ____________________________ Date: __________

Witness: _______________________________ Date: __________

Appendix D

En Route Strategic Team Concept Roles and Responsibilities

En Route Strategic Team Concept Roles and Responsibilities

A) EN ROUTE STRATEGIC TEAM CONCEPT AND INTENT:

1) The intent of the Strategic Team Concept is to distribute workload among sectors and task load among controllers whether one, two, or three people are working the sector(s) involved.
2) There are no absolute divisions of responsibilities among operating positions. The tasks to be completed remain the same no matter the number of staffed positions. The team, as a whole, has responsibility for the safe and efficient operation of sector(s).
3) The roles of each position as a whole will move the approach to air traffic control from dynamic to more trajectory-based.

B) TERMS: The following terms will be used in Genera Air Route Traffic Control Center for the purpose of standardization:

1) ***Sector:*** The area of control responsibility (delegated airspace which consists of defined vertical and geographical limits).
2) ***Radar Position (R)***: That position that is in direct communication with and has primary responsibility for the aircraft and that uses radar information as the primary means of separation.
3) ***Radar Associate (RA)***: That position sometimes referred to as "D-side" or "Manual Controller".
4) ***Airspace Coordinator (AC):*** That position which may initiate control instructions to aircraft via landline coordination, but without direct communication with aircraft.
5) ***Downstream:*** Refers to the sector where the conflict actually will occur if no corrective action is taken. It also refers to the sector where there will be a violation of flow rate conformance if no corrective action is taken.
6) ***Upstream:*** Refers to the sector where the aircraft geographically reside during the time period that the conflict and / or nonconformance is being detected and / or resolved, also, the sector an aircraft traverses before it arrives in the current sector.

C) ROLES:

1) **Radar Position:** The radar controller's area of responsibility defines geographical and vertical limits of the sector(s). The role of the radar controller includes the safe and efficient use of airspace.
2) **Upstream Radar Associate Position:** The role of the radar associate controller is to maintain the flight progress strips and assist the radar controller in every capacity. When the Multi-Sector planner or Airspace Coordinator position is not staffed, the upstream radar associate controller shall also strategically plan conflict and spacing resolutions in order to alleviate the task load of the upstream radar controller, and to the extent possible the downstream radar controller.
3) **Airspace Coordinator Position:** The role of the airspace coordinator position is to remove some of the workload of the downstream radar controller, resolving potential problems before that aircraft arrive in the sector that would have owned the pending problem. The geographical limitations of the AC are confined to the combination of the geographical limitations of the combined sectors of which the AC is strategically assessing future traffic situations. The AC shall be radar qualified on all sectors being viewed. These sectors would mainly be determined around traffic flows. The AC would effect inter-sector planning (i.e. planning that spans across sector boundaries) of air traffic. The AC will push downstream constraints upstream so that aircraft conflicts and flow conformance problems can be solved earlier. This alleviates the problem of a controller issuing inefficient clearances in a tactical situation involving multiple conflicts and / or problems. It is not the role of the AC to address and solve all conflicts within the MSP area. It is the role of the AC to anticipate the future traffic situations and initiate solutions for the radar controllers of the affected sectors. The preliminary aim of the "initiated solutions" is to redistribute workload from overloaded sectors to underloaded sectors, balancing aircraft flows between sectors when possible and when appropriate. The AC will work cooperatively with the radar controller(s), with the main focus on protecting each sector's internal airspace and creating a conflict-free flow of traffic that meets all flow restraints.

4) **UPSTREAM RADAR ASSOCIATE CONTROLLER:**
   a) Manage and scan flight strips
   b) Operate interphones
   c) Accept and initiate non-automated handoffs
   d) Accept and initiate automated handoffs which are necessary for the continued smooth operation of the sector
   e) Coordinate, including point outs
   f) Monitor radios when not performing higher priority duties
   g) Ensure strip marking is completed on instructions issued or received
   h) Ensure computer entries are completed on instructions issued or received
   i) When the MSP position is not staffed:
      1) Assess upstream traffic situations and dynamically initiate control instructions to adjacent sectors via landline communications in order to resolve conflictions
      2) To the extent possible, assess downstream traffic situations and dynamically initiate control instructions to adjacent sectors via landline communications in order to resolve conflictions

3) Analyze traffic sequencing of arrival flows and initiate control actions in order to achieve required spacing where appropriate

j) Keep the radar controller informed of all control actions within that controllers sector of responsibility

5) AIRSPACE COORDINATOR

a) Analyze potential traffic conflictions for upstream sector and initiate control actions to resolve conflictions via verbal landline coordination.

b) Analyze traffic sequencing of inbound arrival flows, keeping an overview of the different inbound arrival flows and balance workload among sectors by re-routing aircraft into a sector with a laterally adjacent boundary via verbal landline communication. If the AC is changing any aspect of an aircraft's route, the AC shall coordinate with the Traffic Management Unit if the aircraft is in a flow of metered airport traffic.

c) For overloaded upper sectors, maintain climbing traffic at intermediate altitudes in lower sectors via landline communications with the sector in which the aircraft currently resides.

d) For overloaded lower sectors, initiate anticipated climb to aircraft with a higher requested altitude, or according to aircraft performance, force the climb of aircraft into the upper sector via verbal landline communication with the sector in which the aircraft currently resides.

e) Ensure that any control actions initiated by the AC adhere to crossing restrictions, preferred routings, mile-in-trail restrictions, and any other TMU initiatives.

f) Ensure any actions taken by the AC adhere to the requirements specified in intra-Center SOP's or inter-Center LOAs.

g) Monitor weather situations, TMU initiatives, NAVAID and frequency outages, holding stacks, and any unusual situations, and take these into account prior to initiating control instructions.

h) Monitor compliance of any and all control instructions initiated by the AC, and ensure they are adhered to unless coordination has been affected.

i) The AC shall not accept or initiate hand-offs, automatic or manual, nor shall he directly communicate with any aircraft. All communication shall be to affected sectors via interphones.

j) Any operational error resulting from the actions of the AC shall be the responsibility of the radar controller owning the airspace.

Appendix E

Information Requirements Questionnaire All

Table E-1. Flight Data: Means and Standard Deviations

Flight Data		North Radar						Experimental Position						South Radar						Position Collapsed					
		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CP	QA	9.20	1.62	8.79	1.52	8.99	1.54	9.77	0.49	9.67	0.53	9.72	0.50	10.0	0.00	9.49	0.66	9.74	0.53	9.66	1.00	9.32	1.05	9.49	1.03
	QB	7.10	2.42	5.66	2.05	6.38	2.31	7.59	2.02	7.09	2.29	7.34	2.12	6.50	3.34	6.86	2.40	6.68	2.84	7.06	2.60	6.54	2.26	6.80	2.43
	QC	7.40	2.84	6.21	1.85	6.80	2.41	7.53	2.70	5.93	3.18	6.73	2.99	9.70	0.48	8.31	1.80	9.00	1.47	8.21	2.45	6.81	2.52	7.51	2.56
	QD	6.60	2.32	6.80	2.02	6.70	2.12	6.55	3.40	5.55	3.61	6.05	3.45	7.80	3.43	7.30	2.85	7.55	3.08	6.98	3.04	6.55	2.90	6.77	2.95
	QE	3.30	1.89	3.23	1.98	3.27	1.88	2.58	1.76	2.68	2.35	2.63	2.02	5.20	3.97	6.63	3.65	5.92	3.78	3.69	2.87	4.18	3.20	3.94	3.02
	QF	3.00	1.94	2.55	1.21	2.78	1.59	2.51	2.18	2.91	2.28	2.71	2.18	2.40	2.17	3.05	2.63	2.73	2.37	2.64	2.04	2.84	2.06	2.74	2.04
	QG	6.90	3.03	6.81	2.08	6.85	2.53	8.48	2.34	8.18	2.31	8.33	2.27	7.90	3.25	7.71	2.81	7.80	2.96	7.76	2.88	7.56	2.41	7.66	2.63
	QH	6.40	2.72	6.66	2.19	6.53	2.41	7.64	1.92	6.84	2.43	7.24	2.17	7.50	2.80	7.66	1.89	7.58	2.33	7.18	2.49	7.05	2.15	7.12	2.31
	QI	3.30	2.31	2.52	1.19	2.91	1.83	1.91	1.00	1.81	1.04	1.86	0.99	5.70	3.53	4.72	3.29	5.21	3.36	3.64	2.89	3.02	2.39	3.33	2.65
FPM	QA	7.70	3.30	6.99	3.72	7.34	3.44	8.87	2.81	9.27	0.96	9.07	2.05	9.50	0.97	9.39	0.65	9.44	0.81	8.69	2.59	8.55	2.45	8.62	2.50
	QB	5.10	3.00	4.66	2.69	4.88	2.78	5.79	3.55	5.79	2.94	5.79	3.17	5.00	3.62	5.86	2.96	5.43	3.25	5.30	3.30	5.44	2.82	5.37	3.04
	QC	6.30	3.37	5.31	3.22	5.80	3.25	5.53	3.45	5.43	3.31	5.48	3.29	8.60	2.17	7.11	2.36	7.85	2.33	6.81	3.23	5.95	3.01	6.38	3.12
	QD	6.50	2.59	6.00	2.89	6.25	2.68	6.75	3.12	7.55	2.24	7.15	2.68	6.40	3.37	6.90	2.40	6.65	2.86	6.55	2.94	6.82	2.52	6.68	2.72
	QE	4.30	1.95	3.63	2.10	3.97	2.00	3.38	3.20	3.48	3.17	3.43	3.10	3.80	3.16	4.63	2.81	4.22	2.94	3.83	2.76	3.92	2.68	3.87	2.70
	QF	3.90	2.92	3.05	2.06	3.48	2.50	2.51	2.84	3.01	2.75	2.76	2.73	2.60	2.80	3.85	3.11	3.23	2.95	3.00	2.83	3.31	2.61	3.16	2.70
	QG	5.80	3.29	6.31	2.65	6.05	2.92	4.38	3.93	4.58	3.79	4.48	3.76	7.90	3.03	7.31	2.57	7.60	2.75	6.03	3.63	6.06	3.16	6.05	3.38
	QH	5.50	2.46	5.46	2.76	5.48	2.55	6.04	2.83	5.64	3.11	5.84	2.90	5.70	2.98	7.66	1.70	6.68	2.57	5.75	2.68	6.25	2.70	6.00	2.68
	QI	3.30	2.63	2.82	1.69	3.06	2.16	2.21	2.82	2.31	2.79	2.26	2.73	4.80	2.97	4.42	3.05	4.61	2.94	3.44	2.92	3.18	2.65	3.31	2.77
DRA	QA	9.20	1.40	8.19	2.80	8.69	2.22	8.67	2.79	8.77	2.78	8.72	2.71	8.10	3.75	8.69	2.43	8.39	3.09	8.66	2.76	8.55	2.60	8.60	2.66
	QB	6.70	3.13	5.26	2.97	5.98	3.06	5.59	3.75	4.89	3.66	5.24	3.62	5.80	4.21	6.46	3.18	6.13	3.65	6.03	3.62	5.54	3.24	5.78	3.42
	QC	6.80	3.29	5.31	3.26	6.05	3.28	5.13	3.46	3.53	2.75	4.33	3.15	6.20	4.18	6.81	3.07	6.50	3.59	6.04	3.61	5.21	3.23	5.63	3.42
	QD	6.80	2.53	5.80	2.92	6.30	2.71	5.35	3.90	4.45	3.59	4.90	3.68	5.60	4.35	7.10	2.83	6.35	3.65	5.92	3.61	5.78	3.22	5.85	3.39
	QE	5.30	2.21	3.53	1.94	4.42	2.22	1.68	1.02	1.68	1.02	1.68	0.99	3.80	3.29	5.03	3.27	4.42	3.26	3.59	2.74	3.42	2.60	3.51	2.65
	QF	4.00	2.87	2.75	1.51	3.38	2.32	1.61	0.87	2.51	2.33	2.06	1.77	2.61	2.76	3.17	2.60	2.89	2.62	2.74	2.48	2.81	2.13	2.78	2.29
	QG	6.90	2.42	6.61	2.44	6.75	2.37	5.98	4.21	5.28	4.21	5.63	4.11	6.40	4.27	6.81	3.38	6.60	3.76	6.43	3.63	6.23	3.37	6.33	3.47
	QH	5.90	2.42	5.66	3.03	5.78	2.67	6.14	3.18	5.54	3.45	5.84	3.24	6.80	3.74	7.96	1.64	7.38	2.87	6.28	3.07	6.39	2.94	6.33	2.98
	QI	3.80	2.94	2.12	1.01	2.96	2.31	1.41	0.71	1.41	0.71	1.41	0.69	3.80	3.08	4.32	2.94	4.06	2.94	3.00	2.67	2.62	2.18	2.81	2.42
LS	QA	7.70	2.95	8.39	2.15	8.04	2.53	6.87	3.83	8.37	2.71	7.62	3.32	8.40	2.88	9.29	0.62	8.84	2.08	7.66	3.19	8.68	2.01	8.17	2.69
	QB	5.80	2.78	6.16	2.26	5.98	2.47	4.19	3.00	4.49	2.45	4.34	2.67	5.70	3.27	7.46	1.76	6.58	2.71	5.23	3.01	6.04	2.44	5.63	2.75
	QC	5.70	3.20	5.81	2.92	5.75	2.98	3.83	3.31	2.73	2.45	3.28	2.89	7.80	2.90	7.51	1.87	7.65	2.38	5.78	3.45	5.35	3.11	5.56	3.26
	QD	5.80	2.57	7.40	2.04	6.60	2.40	6.35	2.87	5.65	2.77	6.00	2.77	7.00	3.02	7.90	1.94	7.45	2.51	6.38	2.77	6.98	2.41	6.68	2.59
	QE	4.10	2.02	3.93	2.54	4.02	2.24	3.78	2.70	3.48	2.72	3.63	2.64	3.00	1.89	5.73	2.67	4.37	2.65	3.63	2.20	4.38	2.73	4.01	2.49
	QF	3.00	2.62	4.15	3.09	3.58	2.85	2.91	2.89	3.71	3.13	3.31	2.96	3.90	3.54	5.55	3.52	4.73	3.54	3.27	2.97	4.47	3.24	3.87	3.14
	QG	5.90	3.00	7.51	1.81	6.70	2.55	6.78	3.55	6.18	3.64	6.48	3.51	7.50	3.27	8.41	1.54	7.95	2.53	6.73	3.24	7.36	2.60	7.05	2.93
	QH	4.90	1.60	6.46	2.74	5.68	2.32	6.14	3.42	6.34	2.83	6.24	3.05	5.50	3.60	7.56	1.83	6.53	2.97	5.51	2.95	6.79	2.48	6.15	2.78
	QI	2.80	2.53	3.22	2.70	3.01	2.55	1.71	1.17	1.81	1.14	1.76	1.12	3.30	2.63	3.72	3.02	3.51	2.76	2.60	2.24	2.92	2.48	2.76	2.35
Automation Collapsed	QA	8.45	2.48	8.09	2.66	8.27	2.56	8.55	2.86	9.02	2.00	8.78	2.46	9.00	2.45	9.21	1.32	9.11	1.96	8.67	2.59	8.77	2.11	8.72	2.36
	QB	6.18	2.85	5.43	2.48	5.80	2.68	5.79	3.27	5.56	2.95	5.68	3.09	5.75	3.53	6.66	2.60	6.20	3.11	5.90	3.20	5.89	2.72	5.90	2.96
	QC	6.55	3.12	5.66	2.78	6.10	2.97	5.50	3.39	4.40	3.13	4.95	3.29	8.08	2.96	7.43	2.31	7.75	2.66	6.71	3.31	5.83	3.01	6.27	3.19
	QD	6.43	2.44	6.50	2.49	6.46	2.45	6.25	3.26	5.80	3.19	6.02	3.21	6.70	3.53	7.30	2.46	7.00	3.04	6.46	3.09	6.53	2.78	6.50	2.93
	QE	4.25	2.07	3.58	2.08	3.92	2.09	2.86	2.38	2.83	2.47	2.85	2.41	3.95	3.15	5.51	3.10	4.73	3.20	3.69	2.62	3.97	2.80	3.83	2.71
	QF	3.48	2.56	3.13	2.10	3.30	2.34	2.39	2.30	3.04	2.58	2.71	2.45	2.88	2.81	3.91	3.04	3.39	2.96	2.91	2.58	3.36	2.61	3.14	2.60
	QG	6.38	2.89	6.81	2.23	6.59	2.57	6.40	3.75	6.05	3.68	6.23	3.70	7.43	3.41	7.56	2.62	7.49	3.02	6.73	3.38	6.81	2.95	6.77	3.16
	QH	5.68	2.31	6.06	2.64	5.87	2.48	6.49	2.86	6.09	2.91	6.29	2.87	6.38	3.28	7.71	1.71	7.04	2.68	6.18	2.84	6.62	2.57	6.40	2.72
	QI	3.30	2.53	2.67	1.75	2.99	2.19	1.81	1.61	1.83	1.60	1.82	1.60	4.40	3.10	4.30	2.98	4.35	3.02	3.17	2.69	2.93	2.41	3.05	2.55

Information Requirements Questionnaire All

Table E-2. Radar and Data Block: Means and Standard Deviations

Radar/ Data Block		North Radar						Experimental Position						South Radar						Position Collapsed					
		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CP	QJ	9.50	0.97	9.20	0.99	9.35	0.97	9.78	0.48	9.38	0.98	9.58	0.78	9.10	2.23	9.50	0.64	9.30	1.61	9.46	1.41	9.36	0.86	9.41	1.16
	QK	9.30	1.57	9.07	1.53	9.19	1.51	9.79	0.44	9.39	0.97	9.59	0.76	9.70	0.67	9.57	0.55	9.64	0.60	9.60	1.00	9.35	1.07	9.47	1.04
	QL	7.00	2.16	5.57	1.16	6.29	1.84	7.09	3.25	6.59	3.06	6.84	3.08	4.30	2.83	5.07	2.72	4.69	2.73	6.13	2.99	5.75	2.46	5.94	2.72
	QM	7.10	2.28	6.13	1.42	6.62	1.92	8.63	1.91	7.83	1.84	8.23	1.87	8.60	1.43	8.23	1.75	8.42	1.57	8.11	1.98	7.40	1.87	7.76	1.94
	QN	8.40	1.71	8.10	1.42	8.25	1.54	9.48	0.90	8.08	1.97	8.78	1.66	8.80	2.57	9.10	1.16	8.95	1.95	8.89	1.85	8.43	1.58	8.66	1.72
	QO	7.80	1.62	7.28	1.12	7.54	1.38	8.92	1.71	6.62	3.07	7.77	2.69	7.70	3.13	8.48	1.43	8.09	2.40	8.14	2.25	7.46	2.13	7.80	2.20
	QP	7.70	1.95	6.40	1.81	7.05	1.95	8.85	1.80	7.15	2.98	8.00	2.55	7.50	2.99	6.30	2.56	6.90	2.78	8.02	2.31	6.62	2.44	7.32	2.46
FPM	QJ	8.20	2.90	7.80	3.38	8.00	3.07	8.68	2.79	8.28	2.70	8.48	2.68	8.60	2.80	9.50	0.64	9.05	2.03	8.49	2.74	8.53	2.55	8.51	2.62
	QK	8.20	2.90	7.87	3.40	8.04	3.08	8.69	2.79	9.09	1.60	8.89	2.22	9.70	0.67	9.57	0.55	9.64	0.60	8.86	2.36	8.85	2.24	8.86	2.28
	QL	6.40	3.10	5.47	2.59	5.94	2.82	5.59	2.95	5.79	2.74	5.69	2.77	5.50	2.88	6.37	2.55	5.94	2.68	5.83	2.90	5.88	2.56	5.86	2.71
	QM	6.10	2.73	5.73	2.70	5.92	2.65	4.93	2.82	5.63	3.28	5.28	3.00	6.40	2.80	6.83	2.51	6.62	2.59	5.81	2.76	6.07	2.80	5.94	2.76
	QN	7.40	2.59	7.00	3.08	7.20	2.78	7.78	2.74	7.38	2.83	7.58	2.72	8.20	2.49	8.00	2.69	8.10	2.52	7.79	2.54	7.46	2.80	7.63	2.66
	QO	6.90	3.21	6.78	3.03	6.84	3.04	7.02	2.75	6.32	3.17	6.67	2.91	7.60	3.17	8.48	1.43	8.04	2.43	7.17	2.96	7.19	2.74	7.18	2.83
	QP	5.70	3.83	5.70	3.25	5.70	3.46	5.65	3.42	5.95	3.18	5.80	3.22	7.50	2.37	7.10	2.40	7.30	2.33	6.28	3.27	6.25	2.93	6.27	3.08
DRA	QJ	8.90	1.45	8.20	2.81	8.55	2.20	8.38	3.02	7.88	3.44	8.13	3.16	8.70	2.87	9.40	0.63	9.05	2.05	8.66	2.47	8.49	2.59	8.58	2.51
	QK	8.70	1.57	8.27	2.82	8.49	2.23	8.59	2.84	8.69	2.79	8.64	2.74	8.20	3.05	9.47	0.55	8.84	2.23	8.50	2.49	8.81	2.29	8.66	2.38
	QL	7.00	2.62	5.27	2.62	6.14	2.70	4.89	3.44	3.79	3.25	4.34	3.31	6.20	3.01	7.47	2.04	6.84	2.59	6.03	3.07	5.51	3.01	5.77	3.03
	QM	6.00	2.98	5.63	2.87	5.82	2.85	4.73	3.04	4.33	3.39	4.53	3.14	6.70	3.09	6.83	2.42	6.77	2.70	5.81	3.05	5.60	3.00	5.71	3.00
	QN	8.20	2.04	7.40	2.70	7.80	2.37	6.28	3.36	5.18	3.66	5.73	3.46	7.60	3.37	8.90	1.06	8.25	2.52	7.36	3.00	7.16	3.03	7.26	2.99
	QO	7.10	2.08	6.08	2.86	6.59	2.49	5.52	2.89	5.32	3.14	5.42	2.94	7.10	3.73	8.68	1.34	7.89	2.84	6.57	2.97	6.69	2.88	6.63	2.90
	QP	6.10	2.73	5.30	2.60	5.70	2.63	5.25	3.87	4.85	3.32	5.05	3.51	7.50	3.10	7.50	2.15	7.50	2.60	6.28	3.29	5.88	2.89	6.08	3.08
LS	QJ	7.80	1.99	8.90	1.25	8.35	1.71	8.68	2.36	8.78	1.55	8.73	1.94	7.70	3.68	9.40	0.63	8.55	2.72	8.06	2.71	9.03	1.20	8.54	2.14
	QK	7.60	2.17	8.97	1.25	8.29	1.86	8.89	1.85	8.99	1.70	8.94	1.73	8.60	2.80	9.47	0.55	9.04	2.01	8.36	2.30	9.15	1.24	8.76	1.87
	QL	6.10	2.51	6.37	2.42	6.24	2.41	5.69	3.13	5.59	2.50	5.64	2.76	6.20	2.78	6.97	1.90	6.59	2.35	6.00	2.73	6.31	2.28	6.16	2.50
	QM	5.30	2.00	6.33	2.57	5.82	2.30	5.33	3.21	5.33	3.21	5.33	3.12	6.20	2.94	7.03	2.13	6.62	2.53	5.61	2.70	6.23	2.67	5.92	2.68
	QN	7.50	1.84	8.40	1.48	7.95	1.69	6.38	3.26	5.28	3.60	5.83	3.39	8.30	3.02	9.00	1.12	8.65	2.25	7.39	2.80	7.56	2.80	7.48	2.78
	QO	6.30	2.63	7.08	2.58	6.69	2.57	6.92	3.00	6.62	3.51	6.77	3.18	7.20	3.79	8.78	1.40	7.99	2.90	6.81	3.09	7.49	2.72	7.15	2.91
	QP	5.00	3.30	5.70	3.04	5.35	3.11	6.35	3.74	5.75	3.21	6.05	3.41	7.30	3.37	7.80	1.85	7.55	2.66	6.22	3.49	6.42	2.85	6.32	3.16
Automation Collapsed	QJ	8.60	2.00	8.53	2.32	8.56	2.15	8.88	2.35	8.58	2.35	8.73	2.34	8.53	2.87	9.45	0.61	8.99	2.12	8.67	2.42	8.85	1.97	8.76	2.20
	QK	8.45	2.14	8.55	2.38	8.50	2.25	8.99	2.17	9.04	1.83	9.02	1.99	9.05	2.15	9.52	0.53	9.29	1.57	8.83	2.15	9.04	1.79	8.94	1.98
	QL	6.63	2.55	5.67	2.23	6.15	2.43	5.82	3.18	5.44	2.98	5.63	3.06	5.55	2.87	6.47	2.41	6.01	2.68	6.00	2.89	5.86	2.58	5.93	2.73
	QM	6.13	2.51	5.96	2.38	6.04	2.43	5.91	3.13	5.78	3.16	5.85	3.12	6.98	2.72	7.23	2.21	7.10	2.47	6.34	2.81	6.32	2.67	6.33	2.74
	QN	7.88	2.04	7.73	2.27	7.80	2.15	7.48	2.95	6.48	3.24	6.98	3.12	8.23	2.81	8.75	1.65	8.49	2.30	7.86	2.62	7.65	2.63	7.76	2.62
	QO	7.03	2.42	6.80	2.46	6.91	2.43	7.09	2.81	6.22	3.14	6.66	3.00	7.40	3.34	8.60	1.35	8.00	2.60	7.17	2.86	7.21	2.62	7.19	2.74
	QP	6.13	3.08	5.77	2.65	5.95	2.86	6.52	3.48	5.92	3.16	6.22	3.32	7.45	2.86	7.17	2.24	7.31	2.56	6.70	3.18	6.29	2.76	6.50	2.98

Table E-3. Assigned Control Actions: Means and Standard Deviations

Assigned Control Actions		North Radar						Experimental Position						South Radar						Position Collapsed					
		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CP	QQ	9.10	1.60	8.99	1.54	9.05	1.53	9.37	0.86	8.77	1.69	9.07	1.34	9.40	1.58	9.39	0.65	9.40	1.17	9.29	1.35	9.05	1.35	9.17	1.34
	QR	6.80	1.69	6.21	1.59	6.50	1.62	7.15	2.87	5.45	2.73	6.30	2.86	6.50	3.63	7.71	1.45	7.10	2.76	6.82	2.76	6.45	2.16	6.64	2.46
	QS	6.40	1.96	5.99	1.61	6.19	1.75	6.92	3.24	5.12	2.29	6.02	2.88	6.40	3.17	6.39	2.78	6.39	2.90	6.57	2.76	5.83	2.26	6.20	2.53
FPM	QQ	8.20	2.62	7.79	3.38	8.00	2.95	8.37	3.02	9.07	1.60	8.72	2.38	8.90	1.85	9.49	0.66	9.20	1.39	8.49	2.47	8.79	2.24	8.64	2.34
	QR	6.60	2.67	5.71	3.04	6.15	2.82	6.05	3.37	5.85	3.59	5.95	3.39	6.70	2.98	7.91	1.88	7.30	2.50	6.45	2.93	6.49	3.00	6.47	2.94
	QS	5.70	3.13	5.49	3.12	5.59	3.04	6.02	3.37	5.92	3.61	5.97	3.40	6.50	2.88	7.09	2.17	6.79	2.50	6.07	3.04	6.17	3.00	6.12	2.99
DRA	QQ	8.70	1.49	8.19	2.80	8.45	2.20	7.97	3.70	7.97	3.70	7.97	3.61	8.50	2.84	9.39	0.65	8.95	2.05	8.39	2.75	8.52	2.69	8.46	2.70
	QR	7.10	2.42	6.11	3.02	6.60	2.71	5.85	4.00	5.05	3.88	5.45	3.86	6.30	3.40	7.91	1.88	7.10	2.80	6.42	3.26	6.35	3.17	6.39	3.19
	QS	6.60	2.59	5.69	2.85	6.14	2.69	6.02	3.77	5.02	3.87	5.52	3.75	6.00	3.27	7.69	1.82	6.84	2.71	6.21	3.14	6.13	3.08	6.17	3.09
LS	QQ	8.10	1.60	8.79	1.37	8.45	1.49	8.57	2.75	8.57	2.75	8.57	2.68	8.50	2.95	9.39	0.65	8.95	2.13	8.39	2.43	8.92	1.79	8.66	2.13
	QR	6.60	1.90	6.81	2.51	6.70	2.17	5.95	3.42	5.25	3.10	5.60	3.20	6.70	3.27	8.11	1.82	7.40	2.67	6.42	2.86	6.72	2.72	6.57	2.77
	QS	5.90	2.51	6.39	3.01	6.14	2.71	5.82	3.43	5.42	2.88	5.62	3.09	6.80	3.22	7.99	1.93	7.39	2.66	6.17	3.01	6.60	2.78	6.39	2.88
Auto Coll.	QQ	8.53	1.85	8.44	2.38	8.48	2.12	8.57	2.73	8.60	2.52	8.59	2.61	8.83	2.32	9.42	0.62	9.12	1.71	8.64	2.31	8.82	2.06	8.73	2.19
	QR	6.78	2.13	6.21	2.53	6.49	2.34	6.25	3.35	5.40	3.24	5.83	3.30	6.55	3.20	7.91	1.70	7.23	2.64	6.53	2.93	6.50	2.75	6.52	2.84
	QS	6.15	2.51	5.89	2.63	6.02	2.56	6.20	3.35	5.37	3.11	5.78	3.24	6.43	3.03	7.29	2.21	6.86	2.67	6.26	2.96	6.18	2.78	6.22	2.86

Table E-4. Map Display Data: Means and Standard Deviations

Map Display Data		North Radar						Experimental Position						South Radar						Position Collapsed					
		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CP	QT	8.80	1.75	8.33	1.61	8.56	1.65	9.56	0.75	8.66	1.56	9.11	1.28	9.70	0.67	8.43	1.93	9.06	1.55	9.35	1.20	8.47	1.65	8.91	1.50
	QU	8.30	1.77	8.06	1.87	8.18	1.78	9.74	0.57	8.54	1.64	9.14	1.34	9.60	0.70	8.86	1.57	9.23	1.24	9.21	1.29	8.49	1.67	8.85	1.53
	QV	7.60	2.27	7.13	1.95	7.37	2.07	9.43	1.00	9.23	1.07	9.33	1.01	9.00	1.25	8.43	1.79	8.72	1.53	8.68	1.74	8.26	1.82	8.47	1.78
	QW	5.50	2.27	4.34	1.70	4.92	2.04	7.46	3.09	6.26	3.63	6.86	3.34	6.40	3.03	6.74	1.95	6.57	2.48	6.45	2.84	5.78	2.70	6.12	2.77
FPM	QT	7.10	3.70	7.03	3.56	7.06	3.53	7.96	3.70	8.46	2.75	8.21	3.19	9.40	0.97	9.23	0.83	9.31	0.88	8.15	3.12	8.24	2.71	8.20	2.90
	QU	6.90	3.60	6.96	3.52	6.93	3.47	8.44	2.91	9.14	1.34	8.79	2.23	9.10	1.29	9.16	0.89	9.13	1.08	8.15	2.84	8.42	2.40	8.28	2.61
	QV	5.40	2.88	5.83	3.09	5.62	2.91	6.73	3.06	8.03	2.15	7.38	2.66	6.70	2.91	8.13	1.75	7.42	2.45	6.28	2.92	7.33	2.55	6.80	2.77
	QW	4.70	2.79	4.24	1.99	4.47	2.37	5.66	3.20	5.26	3.33	5.46	3.18	5.80	2.94	6.84	2.58	6.32	2.74	5.39	2.92	5.44	2.81	5.42	2.84
DRA	QT	8.70	1.25	8.23	2.72	8.46	2.08	8.46	2.75	8.46	2.75	8.46	2.68	8.60	2.80	9.33	0.72	8.96	2.02	8.59	2.30	8.67	2.25	8.63	2.25
	QU	8.30	1.70	8.16	2.72	8.23	2.21	8.24	2.86	8.08	2.79	8.16	2.75	7.80	3.65	9.16	0.76	8.48	2.66	8.11	2.76	8.47	2.27	8.29	2.51
	QV	6.00	2.71	6.33	3.20	6.17	2.89	7.43	2.83	7.53	2.91	7.48	2.80	6.70	3.71	8.43	1.79	7.57	2.97	6.71	3.07	7.43	2.75	7.07	2.91
	QW	5.10	2.77	3.84	2.05	4.47	2.46	5.86	3.14	5.06	3.13	5.46	3.08	5.40	3.53	7.24	2.44	6.32	3.10	5.45	3.07	5.38	2.87	5.42	2.95
LS	QT	8.00	1.89	8.83	1.27	8.41	1.62	8.96	1.57	9.06	0.89	9.01	1.24	7.90	3.48	8.53	2.74	8.21	3.06	8.29	2.42	8.80	1.77	8.55	2.12
	QU	7.70	1.83	8.76	1.29	8.23	1.63	8.14	2.28	8.44	1.34	8.29	1.83	7.10	3.57	8.86	1.57	7.98	2.83	7.65	2.61	8.69	1.37	8.17	2.13
	QV	5.90	2.13	6.83	2.61	6.37	2.37	7.13	2.77	7.83	2.65	7.48	2.66	6.10	2.64	7.93	1.63	7.02	2.33	6.38	2.50	7.53	2.32	6.95	2.46
	QW	5.40	2.84	5.04	2.70	5.22	2.70	4.46	3.36	4.26	2.88	4.36	3.05	5.90	3.48	7.44	2.40	6.67	3.02	5.25	3.18	5.58	2.92	5.42	3.03
Auto Collapsed	QT	8.15	2.35	8.10	2.46	8.13	2.39	8.73	2.44	8.66	2.08	8.69	2.25	8.90	2.33	8.88	1.74	8.89	2.04	8.59	2.38	8.55	2.12	8.57	2.25
	QU	7.80	2.34	7.98	2.49	7.89	2.40	8.64	2.35	8.55	1.84	8.59	2.10	8.40	2.74	9.01	1.22	8.70	2.13	8.28	2.49	8.51	1.95	8.40	2.24
	QV	6.23	2.56	6.53	2.69	6.38	2.61	7.68	2.67	8.16	2.31	7.92	2.49	7.13	2.89	8.23	1.69	7.68	2.42	7.01	2.75	7.64	2.38	7.33	2.59
	QW	5.18	2.59	4.36	2.10	4.77	2.38	5.86	3.26	5.21	3.21	5.53	3.23	5.88	3.15	7.06	2.28	6.47	2.80	5.64	3.01	5.54	2.79	5.59	2.90

Information Requirements Questionnaire All

Table E-5. ANOVA Results: Flight Data

	Wilks	*F*	df 1	df 2	*p* level
ATCS Role	.316	4.575	9	19	.003
Automation	.003	12.864	27	1	.217
Position	.427	1.118	18	38	.373
ATCS Role X Automation	.014	2.615	27	1	.459
ATCS Role X Position	.311	1.674	18	38	.090
Automation X Position	.000	1.790	54	2	.425
ATCS Role X Auto X Position	.001	1.177	54	2	.567

Table E-6. MANOVA Results: Radar and Data Block

	Wilks	*F*	df 1	df 2	*p* level
ATCS Role	.750	0.998	7	21	.460
Automation	.167	1.661	21	7	.252
Position	.506	1.219	14	42	.298
ATCS Role X Automation	.304	0.763	21	7	.707
ATCS Role X Position	.467	1.388	14	42	.201
Automation X Position	.063	0.993	42	14	.536
ATCS Role X Auto X Position	.075	0.882	42	14	.641

Table E-7. MANOVA Results: Assigned Control Actions

	Wilks	*F*	df 1	df 2	*p* level
ATCS Role	.965	0.301	3	25	.824
Automation	.810	0.494	9	19	.861
Position	.832	0.804	6	50	.571
ATCS Role X Automation	.462	2.455	9	19	.048
ATCS Role X Position	.701	1.621	6	50	.161
Automation X Position	.645	0.518	18	38	.932
ATCS Role X Auto X Position	.480	0.935	18	38	.546

Table E-8. MANOVA Results: Map Display Data

	Wilks	*F*	df 1	df 2	*p* level
ATCS Role	.686	2.752	4	24	.051
Automation	.410	1.917	12	16	.112
Position	.769	0.841	8	48	.572
ATCS Role X Automation	.510	1.282	12	16	.316
ATCS Role X Position	.642	1.486	8	48	.187
Automation X Position	.417	0.731	24	32	.784
ATCS Role X Auto X Position	.386	0.812	24	32	.698

Information Requirements Questionnaire All

Table E-9. ANOVA Results: Flight Data- Aircraft Callsign

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	0.709	2.300	0.308	1	27	.583
Conflict Probe	1.748	0.237	7.362	1	29	.011
Flight Path Monitor	0.300	1.531	0.196	1	29	.662
Direct Route Advisory	0.175	2.109	0.083	1	29	.775
Load Smoother	15.770	3.257	4.842	1	29	.036
Automation	18.278	6.719	2.720	3	81	.050
Radar Controller	20.008	5.284	3.786	3	87	.013
Airspace Coordinator	4.031	3.077	1.310	3	87	.276
Position	14.278	16.005	0.892	2	27	.422
ATCS Role X Automation	5.761	1.639	3.516	3	81	.019
ATCS Role X Position	3.666	2.300	1.594	2	27	.222
Automation X Position	7.615	6.719	1.133	6	81	.351
ATCS Role X Auto X Position	0.790	1.639	0.482	6	81	.820

Table E-10. ANOVA Results: Flight Data- Aircraft Type and Equipage

	MS Effect	*MS* Error	*F*	df 1	df 2	*p* level
ATCS Role	0.023	5.676	0.004	1	27	.949
Conflict Probe	50.417	6.244	8.074	1	29	.008
Flight Path Monitor	0.288	2.200	0.131	1	29	.720
Direct Route Advisory	3.670	2.979	1.232	1	29	.276
Load Smoother	9.728	3.724	2.613	1	29	.117
Automation	23.582	9.535	2.473	3	81	.067
Radar Controller	21.831	6.233	3.502	3	87	.019
Airspace Coordinator	7.700	5.074	1.518	3	87	.216
Position	6.051	30.914	0.196	2	27	.823
ATCS Role X Automation	5.949	1.733	3.432	3	81	.021
ATCS Role X Position	14.245	5.676	2.510	2	27	.100
Automation X Position	11.465	9.535	1.202	6	81	.314
ATCS Role X Auto X Position	0.357	1.733	0.206	6	81	.974

Table E-11. ANOVA Results: Flight Data- CID

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	46.253	8.366	5.528	1	27	.026
Automation	49.339	7.686	6.419	3	81	.001
Position	158.677	30.975	5.123	2	27	.013
ATCS Role X Automation	2.361	1.727	1.368	3	81	.259
ATCS Role X Position	1.052	8.366	0.126	2	27	.882
Automation X Position	10.239	7.686	1.332	6	81	.253
ATCS Role X Auto X Position	3.761	1.727	2.178	6	81	.053

Information Requirements Questionnaire All

Table E-12. ANOVA Results: Flight Data- Sector Control Designator

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	0.326	7.680	0.042	1	27	.838
Automation	11.215	9.923	1.130	3	81	.342
Position	19.060	25.683	0.742	2	27	.486
ATCS Role X Automation	3.071	2.333	1.316	3	81	.275
ATCS Role X Position	5.492	7.680	0.715	2	27	.498
Automation X Position	6.824	9.923	0.688	6	81	.660
ATCS Role X Auto X Position	5.196	2.333	2.227	6	81	.049
North Radar						
ATCS Role	0.107	5.785	0.018	1	9	.895
Automation	0.979	6.294	0.156	3	27	.925
ATCS Role X Automation	6.379	1.787	3.571	3	27	.027
Experimental Position						
ATCS Role	4.050	7.051	0.574	1	9	.468
Automation	16.883	14.791	1.141	3	27	.350
ATCS Role X Automation	3.550	2.902	1.223	3	27	.320
South Radar						
ATCS Role	7.152	10.205	0.701	1	9	.424
Automation	7.000	8.685	0.806	3	27	.502
ATCS Role X Automation	3.533	2.311	1.529	3	27	.230
Conflict Probe						
ATCS Role	2.834	3.754	0.755	1	27	.393
Position	11.310	14.216	0.796	2	27	.462
ATCS Role X Position	1.811	3.754	0.482	2	27	.622
Flight Path Monitor						
ATCS Role	1.056	2.799	0.377	1	27	.544
Position	4.071	12.855	0.317	2	27	.731
ATCS Role X Position	2.322	2.799	0.830	2	27	.447
Direct Route Advisory						
ATCS Role	0.272	4.017	0.068	1	27	.797
Position	13.541	19.306	0.701	2	27	.505
ATCS Role X Position	10.009	4.017	2.492	2	27	.102
Load Smoother						
ATCS Role	5.376	4.111	1.308	1	27	.263
Position	10.610	9.076	1.169	2	27	.326
ATCS Role X Position	6.937	4.111	1.688	2	27	.204
Radar Controller						
Automation	5.831	6.308	0.924	3	81	.433
Position	2.063	21.423	0.096	2	27	.909
Automation X Position	4.297	6.308	0.681	6	81	.665
Airspace Coordinator						
Automation	8.456	5.948	1.422	3	81	.243
Position	22.489	11.941	1.883	2	27	.172
Automation X Position	7.722	5.948	1.298	6	81	.267

Information Requirements Questionnaire All

Table E-13. ANOVA Results: Flight Data- Fix Posting Data

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	4.977	3.407	1.461	1	27	.237
North Radar	2.231	0.733	3.045	1	9	.115
Experimental Position	0.003	0.651	0.005	1	9	.946
South Radar	12.121	1.172	10.340	1	9	.011
Automation	2.994	7.337	0.408	3	81	.748
Position	71.358	23.022	3.100	2	27	.061
Radar Controller	5.367	3.524	1.523	2	27	.236
Airspace Coordinator	19.028	3.083	6.172	2	27	.006
ATCS Role X Automation	2.578	1.598	1.613	3	81	.193
ATCS Role X Position	26.223	3.407	7.696	2	27	.002
Automation X Position	14.999	7.337	2.044	6	81	.069
ATCS Role X Auto X Position	2.007	1.598	1.256	6	81	.287

Table E-14. ANOVA Results: Flight Data- Departure Airport

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	11.865	4.273	2.777	1	27	.107
Automation	16.583	6.099	2.719	3	81	.050
Position	10.887	26.862	0.405	2	27	.671
ATCS Role X Automation	3.971	1.653	2.402	3	81	.074
ATCS Role X Position	10.085	4.273	2.360	2	27	.114
Automation X Position	3.960	6.099	0.649	6	81	.690
ATCS Role X Auto X Position	1.596	1.653	0.965	6	81	.454

Table E-15. ANOVA Results: Flight Data- Arrival Airport

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.311	5.998	0.052	1	27	.822
Automation	31.828	8.768	3.630	3	81	.016
Position	33.891	40.043	0.846	2	27	.440
ATCS Role X Automation	2.322	1.948	1.192	3	81	.318
ATCS Role X Position	3.121	5.998	0.520	2	27	.600
Automation X Position	15.432	8.768	1.760	6	81	.118
ATCS Role X Auto X Position	2.160	1.948	1.108	6	81	.365

Table E-16. ANOVA Results: Flight Data- Flight Plan En Route Airways and Fixes

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	11.616	3.179	3.654	1	27	.067
North Radar	0.741	0.483	1.534	1	9	.247
Experimental Position	0.800	0.622	1.286	1	9	.286
South Radar	8.911	1.279	6.965	1	9	.027
Automation	14.811	8.092	1.830	3	81	.148
Position	28.339	21.988	1.289	2	27	.292
Radar Controller	1.946	3.270	0.595	2	27	.559
Airspace Coordinator	8.913	3.022	2.950	2	27	.069
ATCS Role X Automation	5.656	3.080	1.836	3	81	.147
ATCS Role X Position	15.097	3.179	4.748	2	27	.017
Automation X Position	1.724	8.092	0.213	6	81	.972
ATCS Role X Auto X Position	1.218	3.080	0.395	6	81	.880

Table E-17. ANOVA Results: Flight Data- Aircraft Beacon Code

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	3.361	5.370	0.626	1	27	.436
Automation	5.717	5.503	1.039	3	81	.380
Position	128.272	19.511	6.574	2	27	.005
ATCS Role X Automation	2.361	1.418	1.666	3	81	.181
ATCS Role X Position	2.405	5.370	0.448	2	27	.644
Automation X Position	3.729	5.503	0.678	6	81	.668
ATCS Role X Auto X Position	1.974	1.418	1.392	6	81	.228

Table E-18. ANOVA Results: Radar and Data Block- Current Location

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	2.076	6.034	0.344	1	27	.562
Conflict Probe	0.142	0.868	0.164	1	29	.689
Flight Path Monitor	0.019	3.886	0.005	1	29	.944
Direct Route Advisory	0.403	2.845	0.142	1	29	.709
Load Smoother	14.094	2.985	4.721	1	29	.038
Automation	11.311	4.550	2.486	3	81	.066
Radar Controller	10.275	3.390	3.031	3	87	.034
Airspace Coordinator	5.231	2.472	2.116	3	87	.104
Position	3.682	15.279	0.241	2	27	.788
ATCS Role X Automation	4.194	1.532	2.737	3	81	.049
ATCS Role X Position	8.543	6.034	1.416	2	27	.260
Automation X Position	2.424	4.550	0.533	6	81	.782
ATCS Role X Auto X Position	0.465	1.532	0.304	6	81	.933

Table E-19. ANOVA Results: Radar and Data Block- Current Altitude

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	2.588	2.455	1.054	1	27	.314
Automation	8.104	4.691	1.728	3	81	.168
Position	12.821	11.286	1.136	2	27	.336
ATCS Role X Automation	3.015	1.209	2.494	3	81	.066
ATCS Role X Position	1.076	2.455	0.438	2	27	.650
Automation X Position	1.729	4.691	0.369	6	81	.897
ATCS Role X Auto X Position	1.857	1.209	1.536	6	81	.177

Table E-20. ANOVA Results: Radar and Data Block- Current Heading

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	1.099	3.751	0.293	1	27	.593
North Radar	4.541	1.134	4.003	1	9	.076
Experimental Position	0.703	0.944	0.745	1	9	.411
South Radar	4.250	0.735	5.781	1	9	.040
Automation	1.628	7.250	0.225	3	81	.879
North Radar	0.240	1.652	0.145	3	27	.932
Experimental Position	10.440	5.014	2.082	3	27	.126
South Radar	9.242	4.209	2.196	3	27	.112
Position	5.760	27.972	0.206	2	27	.815
Radar Controller	3.131	4.347	0.720	2	27	.496
Airspace Coordinator	2.919	3.584	0.814	2	27	.453
Conflict Probe	12.538	5.389	2.327	2	27	.117
Flight Path Monitor	0.197	6.875	0.029	2	27	.972
Direct Route Advisory	16.533	7.169	2.306	2	27	.119
Load Smoother	2.272	5.427	0.419	2	27	.662
ATCS Role X Automation	2.228	1.914	1.164	3	81	.329
ATCS Role X Position	18.440	3.751	4.915	2	27	.015
Automation X Position	19.107	7.250	2.636	6	81	.022
ATCS Role X Auto X Position	1.757	1.914	0.918	6	81	.486

Table E-21. ANOVA Results: Radar and Data Block- Current Airspeed

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.009	3.444	0.003	1	27	.960
Conflict Probe	7.604	0.989	7.692	1	29	.010
Flight Path Monitor	0.973	1.198	0.812	1	29	.375
Direct Route Advisory	0.674	3.347	0.201	1	29	.657
Load Smoother	5.791	1.705	3.397	1	29	.076
Automation	54.828	5.951	9.213	3	81	.000
Radar Controller	42.275	4.315	9.797	3	87	.000
Airspace Coordinator	17.564	3.127	5.617	3	87	.001
Position	36.663	29.508	1.242	2	27	.305
ATCS Role X Automation	5.011	1.345	3.725	3	81	.015
ATCS Role X Position	1.095	3.444	0.318	2	27	.730
Automation X Position	8.457	5.951	1.421	6	81	.217
ATCS Role X Auto X Position	0.957	1.345	0.711	6	81	.641

Table E-22. ANOVA Results: Radar and Data Block- Interim Altitude

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	2.571	9.481	0.271	1	27	.607
Automation	23.160	5.482	4.225	3	81	.008
North Radar	7.588	3.259	2.328	3	27	.097
Experimental Position	23.099	4.728	4.886	3	27	.008
South Radar	9.913	1.641	6.042	3	27	.003
Position	45.910	20.165	2.277	2	27	.122
Conflict Probe	1.327	2.040	0.650	2	27	.530
Flight Path Monitor	2.044	5.021	0.407	2	27	.670
Direct Route Advisory	18.147	6.227	2.915	2	27	.071
Load Smoother	2.272	5.427	0.419	2	27	.662
ATCS Role X Automation	1.115	1.402	0.795	3	81	.500
ATCS Role X Position	11.711	9.481	1.235	2	27	.307
Automation X Position	13.476	5.482	2.458	6	81	.031
ATCS Role X Auto X Position	2.240	1.402	1.598	6	81	.158

Table E-23. ANOVA Results: Radar and Data Block- Altitude Change Indicator

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	0.069	6.903	0.010	1	27	.921
Conflict Probe	6.991	3.724	1.877	1	29	.181
Flight Path Monitor	0.005	3.785	0.001	1	29	.973
Direct Route Advisory	0.207	2.741	0.075	1	29	.786
Load Smoother	7.018	2.407	2.916	1	29	.098
Automation	13.672	6.693	2.043	3	81	.114
Radar Controller	14.289	3.749	3.812	3	87	.013
Airspace Coordinator	4.100	4.341	0.944	3	87	.423
Position	40.730	26.696	1.526	2	27	.236
ATCS Role X Automation	4.717	1.531	3.082	3	81	.032
ATCS Role X Position	22.547	6.903	3.267	2	27	.054
Automation X Position	4.351	6.693	0.650	6	81	.690
ATCS Role X Auto X Position	1.938	1.531	1.266	6	81	.282

Table E-24. ANOVA Results: Radar and Data Block- Aircraft Handoff Status

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	10.070	6.704	1.502	1	27	.231
Conflict Probe	29.456	3.323	8.864	1	29	.006
Flight Path Monitor	0.018	2.611	0.007	1	29	.934
Direct Route Advisory	2.416	2.961	0.816	1	29	.374
Load Smoother	0.592	3.178	0.186	1	29	.669
Automation	18.571	7.369	2.520	3	81	.064
Radar Controller	23.144	5.340	4.334	3	87	.007
Airspace Coordinator	2.897	4.351	0.666	3	87	.575
Position	41.518	34.129	1.217	2	27	.312
ATCS Role X Automation	7.471	1.984	3.766	3	81	.014
ATCS Role X Position	0.572	6.704	0.085	2	27	.919
Automation X Position	13.046	7.369	1.770	6	81	.116
ATCS Role X Auto X Position	1.213	1.984	0.611	6	81	.721

Information Requirements Questionnaire All

Table E-25. ANOVA Results: Assigned Control Actions- Assigned Altitude

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	1.901	3.857	0.493	1	27	.489
Automation	5.694	4.631	1.230	3	81	.304
Position	9.381	19.273	0.487	2	27	.620
ATCS Role X Automation	1.561	0.986	1.583	3	81	.200
ATCS Role X Position	2.629	3.857	0.682	2	27	.514
Automation X Position	1.590	4.631	0.343	6	81	.912
ATCS Role X Auto X Position	1.115	0.986	1.131	6	81	.352

Table E-26. ANOVA Results: Assigned Control Actions- Assigned Heading

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	0.026	5.867	0.005	1	27	.947
North Radar	1.619	0.955	1.696	1	9	.225
Experimental Position	3.612	0.644	5.613	1	9	.042
South Radar	9.194	2.802	3.281	1	9	.104
Automation	0.726	5.348	0.136	3	81	.938
Position	39.320	39.368	0.999	2	27	.382
Radar Controller	0.690	6.427	0.107	2	27	.899
Airspace Coordinator	16.350	4.882	3.349	2	27	.050
ATCS Role X Automation	1.138	1.318	0.863	3	81	.464
ATCS Role X Position	28.837	5.867	4.915	2	27	.015
Automation X Position	1.876	5.348	0.351	6	81	.907
ATCS Role X Auto X Position	1.238	1.318	0.939	6	81	.472

Table E-27. ANOVA Results: Assigned Control Actions- Assigned Airspeed

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	0.335	4.895	0.068	1	27	.796
Automation	0.811	6.185	0.131	3	81	.941
Position	25.408	39.980	0.636	2	27	.537
ATCS Role X Automation	3.611	1.563	2.310	3	81	.082
ATCS Role X Position	14.773	4.895	3.018	2	27	.066
Automation X Position	2.715	6.185	0.439	6	81	.851
ATCS Role X Auto X Position	1.799	1.563	1.151	6	81	.341

Table E-28. ANOVA Results: Map Display Data- Sector Boundaries

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.138	2.664	0.052	1	27	.822
Conflict Probe	11.651	1.416	8.228	1	29	.008
Flight Path Monitor	0.109	1.358	0.080	1	29	.779
Direct Route Advisory	0.109	1.841	0.059	1	29	.809
Load Smoother	4.035	1.841	2.192	1	29	.149
Automation	5.228	6.234	0.839	3	81	.477
Radar Controller	8.653	4.227	2.047	3	87	.113
Airspace Coordinator	1.831	3.354	0.546	3	87	.652
Position	12.558	15.511	0.810	2	27	.456
ATCS Role X Automation	5.256	1.324	3.968	3	81	.011
ATCS Role X Position	0.014	2.664	0.005	2	27	.995
Automation X Position	6.557	6.234	1.052	6	81	.398
ATCS Role X Auto X Position	1.326	1.324	1.002	6	81	.430

Table E-29. ANOVA Results: Map Display Data- Special Use Airspace Boundaries

	MS Effect	MS Error	F	df 1	df 2	*p* level
ATCS Role	3.290	3.923	0.839	1	27	.368
Conflict Probe	7.938	1.020	7.785	1	29	.009
Flight Path Monitor	1.114	1.254	0.888	1	29	.354
Direct Route Advisory	1.863	2.907	0.641	1	29	.430
Load Smoother	16.199	2.992	5.413	1	29	.027
Automation	5.653	5.015	1.127	3	81	.343
Radar Controller	13.178	4.057	3.248	3	87	.026
Airspace Coordinator	0.416	2.531	0.165	3	87	.920
Position	15.548	16.164	0.962	2	27	.395
ATCS Role X Automation	7.941	1.414	5.617	3	81	.002
ATCS Role X Position	2.480	3.923	0.632	2	27	.539
Automation X Position	6.796	5.015	1.355	6	81	.243
ATCS Role X Auto X Position	1.938	1.414	1.371	6	81	.236

Table E-30. ANOVA Results: Map Display Data- Heavy Weather Location

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	23.688	4.724	5.015	1	27	.034
Conflict Probe	2.563	1.009	2.539	1	29	.122
Flight Path Monitor	16.643	2.368	7.029	1	29	.013
Direct Route Advisory	7.776	2.916	2.667	1	29	.113
Load Smoother	19.953	2.088	9.556	1	29	.004
Automation	35.726	5.146	6.943	3	81	.000
Radar Controller	38.067	3.699	10.291	3	87	.000
Airspace Coordinator	5.408	2.454	2.204	3	87	.093
Position	55.042	24.730	2.226	2	27	.127
ATCS Role X Automation	7.749	1.245	6.226	3	81	.001
ATCS Role X Position	3.553	4.724	0.752	2	27	.481
Automation X Position	1.689	5.146	0.328	6	81	.920
ATCS Role X Auto X Position	1.261	1.245	1.013	6	81	.423

Information Requirements Questionnaire All

Table E-31. ANOVA Results: Map Display Data- VORs

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.515	5.908	0.087	1	27	.770
North Radar	3.313	0.698	4.749	1	9	.057
Experimental Position	2.112	0.948	2.227	1	9	.170
South Radar	7.033	2.785	2.525	1	9	.147
Automation	7.350	8.655	0.849	3	81	.471
Position	57.988	28.372	2.044	2	27	.149
Radar Controller	1.597	5.347	0.299	2	27	.744
Airspace Coordinator	19.065	3.223	5.916	2	27	.007
ATCS Role X Automation	2.683	1.560	1.720	3	81	.169
ATCS Role X Position	24.659	5.908	4.174	2	27	.026
Automation X Position	8.483	8.655	0.980	6	81	.444
ATCS Role X Auto X Position	0.767	1.560	0.491	6	81	.813

Appendix F

Trial Planning Only

Trial Planning Only

Table F-1. Trial Planning: Means and Standard Deviations

Trial Planning		North Radar						Experimental Position						South Radar						Position Collapsed					
		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CP	QNN	6.00	2.83	6.51	3.05	6.25	2.88	7.88	2.23	7.98	2.40	7.93	2.26	7.70	2.26	8.11	2.06	7.90	2.12	7.19	2.52	7.53	2.56	7.36	2.52
	QOO	5.60	2.72	6.26	2.96	5.93	2.78	6.71	2.31	6.71	2.11	6.71	2.16	7.20	1.62	7.46	1.94	7.33	1.75	6.50	2.29	6.81	2.35	6.66	2.30
	QPP	7.00	2.75	7.26	2.33	7.13	2.49	8.16	1.69	7.96	1.64	8.06	1.62	6.50	2.88	7.66	2.61	7.08	2.74	7.22	2.51	7.63	2.17	7.42	2.34
	QQQ	6.30	2.41	7.15	2.31	6.72	2.33	7.89	1.46	7.79	1.63	7.84	1.50	6.30	2.75	7.15	2.75	6.72	2.71	6.83	2.32	7.36	2.21	7.10	2.26
	QRR	5.80	2.39	6.29	2.34	6.04	2.32	6.07	3.04	6.27	2.27	6.17	2.61	5.40	2.32	6.19	2.64	5.79	2.45	5.76	2.53	6.25	2.34	6.00	2.43
	QSS	4.60	2.59	5.56	2.86	5.08	2.70	5.74	2.90	5.04	2.67	5.39	2.74	5.60	3.47	5.76	3.21	5.68	3.26	5.31	2.95	5.46	2.84	5.38	2.87
DRA	QNN	7.10	2.13	7.11	3.02	7.10	2.55	8.68	1.90	8.88	1.93	8.78	1.86	7.60	2.67	8.81	1.09	8.20	2.08	7.79	2.28	8.26	2.25	8.03	2.26
	QOO	6.50	2.27	6.56	3.00	6.53	2.59	8.21	1.92	8.21	1.98	8.21	1.90	7.50	2.72	8.46	1.45	7.98	2.18	7.40	2.36	7.74	2.32	7.57	2.33
	QPP	7.50	2.55	7.16	2.91	7.33	2.67	9.06	1.24	8.96	1.37	9.01	1.27	7.60	2.76	8.56	1.17	8.08	2.12	8.05	2.32	8.23	2.06	8.14	2.18
	QQQ	6.60	1.96	6.45	2.63	6.52	2.25	7.79	1.94	7.29	2.59	7.54	2.24	5.60	3.31	7.45	2.08	6.52	2.85	6.66	2.56	7.06	2.40	6.86	2.47
	QRR	5.50	2.27	5.09	2.49	5.29	2.33	6.37	3.60	6.07	3.15	6.22	3.29	5.20	3.08	6.79	2.08	5.99	2.69	5.69	2.97	5.98	2.62	5.84	2.78
	QSS	5.60	2.84	5.56	2.66	5.58	2.67	6.04	3.12	5.64	2.87	5.84	2.92	5.40	3.31	6.66	2.16	6.03	2.79	5.68	3.00	5.96	2.54	5.82	2.76
LS	QNN	6.60	2.37	8.11	2.06	7.35	2.29	8.08	1.86	8.48	1.66	8.28	1.73	7.50	2.80	8.71	1.12	8.10	2.16	7.39	2.37	8.43	1.62	7.91	2.08
	QOO	6.30	2.41	7.46	2.00	6.88	2.23	7.31	2.50	7.71	1.94	7.51	2.19	6.10	3.28	8.36	1.27	7.23	2.69	6.57	2.71	7.84	1.75	7.21	2.35
	QPP	6.40	2.99	8.16	2.14	7.28	2.69	7.86	2.89	7.56	3.17	7.71	2.95	6.40	3.24	7.86	1.95	7.13	2.71	6.89	3.02	7.86	2.40	7.37	2.75
	QQQ	6.00	2.49	7.55	2.03	6.77	2.35	6.89	2.85	6.59	2.80	6.74	2.75	5.40	3.31	7.55	1.53	6.47	2.74	6.10	2.87	7.23	2.15	6.66	2.58
	QRR	4.20	2.30	4.89	2.31	4.54	2.27	5.47	3.50	5.07	2.91	5.27	3.14	5.20	3.55	7.09	2.27	6.14	3.06	4.96	3.11	5.68	2.63	5.32	2.88
	QSS	3.50	1.58	4.36	2.51	3.93	2.09	5.24	3.15	5.04	2.36	5.14	2.71	5.50	3.60	6.46	2.79	5.98	3.17	4.75	2.95	5.29	2.63	5.02	2.78
Auto Collapsed	QNN	6.57	2.42	7.24	2.74	6.90	2.58	8.21	1.96	8.44	1.99	8.33	1.96	7.60	2.50	8.54	1.47	8.07	2.09	7.46	2.38	8.07	2.19	7.77	2.30
	QOO	6.13	2.42	6.76	2.65	6.45	2.53	7.41	2.27	7.55	2.04	7.48	2.14	6.93	2.61	8.09	1.59	7.51	2.22	6.83	2.47	7.47	2.19	7.15	2.35
	QPP	6.97	2.71	7.53	2.44	7.25	2.57	8.36	2.05	8.16	2.21	8.26	2.12	6.83	2.91	8.03	1.97	7.43	2.54	7.39	2.65	7.91	2.21	7.65	2.45
	QQQ	6.30	2.23	7.05	2.30	6.67	2.28	7.52	2.13	7.22	2.36	7.37	2.24	5.77	3.05	7.38	2.11	6.57	2.72	6.53	2.58	7.22	2.24	6.87	2.43
	QRR	5.17	2.35	5.42	2.38	5.29	2.35	5.97	3.29	5.81	2.75	5.89	3.01	5.27	2.92	6.69	2.29	5.98	2.70	5.47	2.87	5.97	2.52	5.72	2.70
	QSS	4.57	2.47	5.16	2.65	4.86	2.56	5.67	2.97	5.24	2.56	5.46	2.76	5.50	3.34	6.30	2.69	5.90	3.03	5.25	2.96	5.57	2.66	5.41	2.81

Table F-2. ANOVA Results: Trial Planning

	Wilks	*F*	df 1	df 2	*p* level
ATCS Role	.659	1.894	6	22	.127
Automation	.403	1.973	12	16	.102
Position	.674	0.798	12	44	.650
ATCS Role X Automation	.526	1.202	12	16	.359
ATCS Role X Position	.540	1.324	12	44	.240
Automation X Position	.404	0.763	24	32	.751
ATCS Role X Auto X Position	.391	0.798	24	32	.713

Table F-3. ANOVA Results: Trial Plan Conflict Status

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	17.051	3.513	4.854	1	27	.036
Automation	7.606	2.898	2.625	2	54	.082
Position	34.529	18.891	1.828	2	27	.180
ATCS Role X Automation	2.072	1.219	1.701	2	54	.192
ATCS Role X Position	1.910	3.513	0.544	2	27	.587
Automation X Position	1.581	2.898	0.545	4	54	.703
ATCS Role X Auto X Position	1.014	1.219	0.832	4	54	.511

Table F-4. ANOVA Results: Aircraft Trajectory under Trial Plan

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	18.381	4.232	4.343	1	27	.047
Automation	12.772	3.585	3.562	2	54	.035
Position	22.107	17.532	1.261	2	27	.300
ATCS Role X Automation	4.517	1.496	3.019	2	54	.057
ATCS Role X Position	3.945	4.232	0.932	2	27	.406
Automation X Position	3.214	3.585	0.896	4	54	.473
ATCS Role X Auto X Position	1.208	1.496	0.808	4	54	.526

Table F-5. ANOVA Results: If Conflict, Conflicting Aircraft Callsign(s)

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	12.023	3.390	3.547	1	27	.070
Automation	11.039	5.625	1.962	2	54	.150
Position	17.691	17.806	0.994	2	27	.383
ATCS Role X Automation	2.539	1.640	1.548	2	54	.222
ATCS Role X Position	7.286	3.390	2.149	2	27	.136
Automation X Position	2.289	5.625	0.407	4	54	.803
ATCS Role X Auto X Position	1.839	1.640	1.121	4	54	.356

Table F-6. ANOVA Results: If Conflict, Aircraft Trajectory & LOS Point with other Aircraft

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	21.328	4.146	5.145	1	27	.032
Automation	2.822	2.321	1.216	2	54	.304
Position	11.280	23.895	0.472	2	27	.629
ATCS Role X Automation	2.289	1.481	1.545	2	54	.223
ATCS Role X Position	13.808	4.146	3.331	2	27	.051
Automation X Position	2.172	2.321	0.936	4	54	.450
ATCS Role X Auto X Position	1.939	1.481	1.309	4	54	.278

Table F-7. ANOVA Results: If Conflict, Time until LOS with other Aircraft: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	11.390	5.595	2.036	1	27	.165
Automation	7.617	4.015	1.897	2	54	.160
Position	8.284	29.169	0.284	2	27	.755
ATCS Role X Automation	0.706	1.141	0.618	2	54	.543
ATCS Role X Position	10.151	5.595	1.814	2	27	.182
Automation X Position	4.983	4.015	1.241	4	54	.305
ATCS Role X Auto X Position	1.572	1.141	1.378	4	54	.254

Table F-8. ANOVA Results: If Conflict, Closest-Point-of-Approach with other Aircraft

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	4.595	4.862	0.945	1	27	.340
Automation	9.622	4.245	2.267	2	54	.113
Position	16.132	33.470	0.482	2	27	.623
ATCS Role X Automation	0.622	1.002	0.621	2	54	.541
ATCS Role X Position	6.527	4.862	1.343	2	27	.278
Automation X Position	3.964	4.245	0.934	4	54	.451
ATCS Role X Auto X Position	1.414	1.002	1.411	4	54	.243

Appendix G

Probe Type (CP) Only

Probe Type (CP) Only

Table G-1. Probe Type: Means and Standard Deviations

Probe Type		North Radar						Experimental Position						South Radar						Position Collapsed					
		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Aircraft CP	QX	9.30	0.82	8.13	1.81	8.72	1.49	9.36	0.93	8.36	1.97	8.86	1.58	9.50	1.08	8.33	1.65	8.92	1.49	9.39	0.92	8.27	1.76	8.83	1.50
	QZ	7.90	1.37	7.40	1.43	7.65	1.39	8.70	1.83	9.00	1.15	8.85	1.50	7.60	2.32	7.60	2.12	7.60	2.16	8.07	1.87	8.00	1.72	8.03	1.78
	QAA	5.90	2.28	6.22	2.28	6.06	2.23	6.38	3.24	7.68	1.85	7.03	2.65	7.10	2.38	7.12	1.93	7.11	2.11	6.46	2.62	7.00	2.05	6.73	2.35
	QBB	5.30	2.79	4.87	2.30	5.09	2.50	6.34	2.65	6.54	2.52	6.44	2.52	6.10	3.21	6.27	2.97	6.19	3.01	5.91	2.83	5.90	2.63	5.91	2.71
SUA CP	QX	8.30	1.77	8.33	1.09	8.32	1.43	7.36	3.02	7.06	2.22	7.21	2.58	7.90	2.64	8.13	2.44	8.02	2.48	7.85	2.47	7.84	2.02	7.85	2.24
	QZ	7.70	1.77	7.60	1.26	7.65	1.50	7.50	2.95	7.40	2.55	7.45	2.68	6.40	2.55	6.30	2.98	6.35	2.70	7.20	2.46	7.10	2.37	7.15	2.39
	QAA	5.90	2.28	6.32	1.98	6.11	2.09	5.08	2.59	5.28	1.94	5.18	2.23	6.00	2.31	6.32	2.61	6.16	2.40	5.66	2.35	5.97	2.18	5.82	2.25
	QBB	5.80	2.53	5.57	1.75	5.69	2.12	4.94	2.38	5.74	2.10	5.34	2.22	6.00	2.98	5.67	3.18	5.84	3.01	5.58	2.59	5.66	2.34	5.62	2.45
Weather CP	QX	5.20	2.78	5.23	3.09	5.22	2.86	5.46	3.72	5.96	3.41	5.71	3.48	6.40	2.37	8.13	1.55	7.27	2.14	5.69	2.95	6.44	2.98	6.06	2.97
	QZ	5.20	2.53	5.20	2.98	5.20	2.69	5.20	3.58	5.80	2.82	5.50	3.15	6.00	2.05	7.60	1.95	6.80	2.12	5.47	2.73	6.20	2.73	5.83	2.73
	QAA	3.80	2.10	4.12	2.96	3.96	2.50	3.78	2.92	4.68	2.20	4.23	2.56	5.40	2.01	7.22	2.06	6.31	2.19	4.33	2.42	5.34	2.72	4.83	2.61
	QBB	3.20	2.39	3.97	2.87	3.59	2.60	4.04	3.11	4.54	2.77	4.29	2.88	5.90	2.28	6.97	2.30	6.44	2.30	4.38	2.78	5.16	2.89	4.77	2.84
Probe Collapsed	QX	7.60	2.59	7.23	2.54	7.42	2.55	7.39	3.16	7.12	2.71	7.26	2.92	7.93	2.43	8.20	1.86	8.07	2.15	7.64	2.73	7.52	2.42	7.58	2.57
	QZ	6.93	2.26	6.74	2.26	6.83	2.24	7.13	3.15	7.40	2.58	7.27	2.86	6.67	2.34	7.17	2.39	6.92	2.36	6.91	2.59	7.10	2.40	7.01	2.49
	QAA	5.20	2.37	5.55	2.57	5.38	2.46	5.08	3.03	5.88	2.34	5.48	2.71	6.17	2.28	6.88	2.18	6.53	2.24	5.48	2.60	6.10	2.41	5.79	2.52
	QBB	4.77	2.74	4.81	2.36	4.79	2.54	5.11	2.81	5.61	2.54	5.36	2.66	6.00	2.75	6.31	2.80	6.15	2.76	5.29	2.78	5.57	2.62	5.43	2.70

Table G-2. MANOVA Results: Aircraft, Special Use Airspace, and Weather Conflict Probe

	Wilks	*F*	df 1	df 2	*p* level
ATCS Role	.717	2.371	4	24	.081
Probe	.381	4.061	8	20	.005
Position	.690	1.221	8	48	.308
ATCS Role X Probe	.683	1.158	8	20	.370
ATCS Role X Position	.884	0.382	8	48	.925
Probe X Position	.420	1.360	16	40	.211
ATCS Role X Probe X Position	.450	1.228	16	40	.290

Table G-3. ANOVA Results: Conflict Alert Indicator for Involved Aircraft

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.682	2.743	0.249	1	27	.622
Aircraft Cp	18.548	1.688	10.988	1	29	.002
Sua Cp	0.002	1.736	0.001	1	29	.972
Weather Cp	8.543	3.374	2.532	1	29	.122
Probe	118.017	7.826	15.080	2	54	.000
Radar Controller	103.678	4.724	21.948	2	58	.000
Airspace Coordinator	27.544	5.269	5.228	2	58	.008
Position	11.003	8.900	1.236	2	27	.306
ATCS Role X Probe	13.206	2.121	6.226	2	54	.004
ATCS Role X Position	1.736	2.743	0.633	2	27	.539
Probe X Position	9.342	7.826	1.194	4	54	.324
ATCS Role X Probe X Position	1.264	2.121	0.596	4	54	.667

Probe Type (CP) Only

Table G-4. ANOVA Results: Aircraft Trajectory & LOS Point with other Aircraft/SUA/Weather

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	1.636	2.673	0.612	1	27	.441
Probe	73.539	5.556	13.236	2	54	.000
North Radar	20.008	2.360	8.477	2	18	.003
Experimental Position	28.308	3.771	7.506	2	18	.004
South Radar	4.008	2.203	1.820	2	18	.191
Position	3.162	14.805	0.214	2	27	.809
Aircraft Cp	5.003	2.515	1.989	2	27	.156
Sua Cp	4.898	4.805	1.019	2	27	.374
Weather Cp	7.236	5.638	1.283	2	27	.293
ATCS Role X Probe	3.339	2.018	1.655	2	54	.201
ATCS Role X Position	1.902	2.673	0.712	2	27	.500
Probe X Position	15.556	5.556	2.800	4	54	.035
ATCS Role X Probe X Position	1.089	2.018	0.540	4	54	.707

Table G-5. ANOVA Results: Time Until LOS with other Aircraft/SUA/Weather

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	17.447	3.533	4.939	1	27	.035
Probe	54.172	3.504	15.459	2	54	.000
North Radar	15.058	1.855	8.119	2	18	.003
Experimental Position	20.275	1.988	10.199	2	18	.001
South Radar	2.608	1.414	1.845	2	18	.187
Position	24.274	20.229	1.200	2	27	.317
Aircraft Cp	3.418	4.871	0.702	2	27	.505
Sua Cp	3.042	4.289	0.709	2	27	.501
Weather Cp	16.532	4.459	3.708	2	27	.038
ATCS Role X Probe	1.906	1.331	1.431	2	54	.248
ATCS Role X Position	0.858	3.533	0.243	2	27	.786
Probe X Position	10.856	3.504	3.098	4	54	.023
ATCS Role X Probe X Position	2.156	1.331	1.619	4	54	.183

Table G-6. ANOVA Results: Closest-Point-of-Approach with other Aircraft/SUA/Weather

	MS Effect	MS Error	F	df 1	df 2	p level
ATCS Role	3.584	2.594	1.382	1	27	.250
Probe	20.872	6.173	3.381	2	54	.041
Position	28.259	23.522	1.201	2	27	.316
ATCS Role X Probe	2.850	1.777	1.604	2	54	.210
ATCS Role X Position	0.800	2.594	0.309	2	27	.737
Probe X Position	13.731	6.173	2.224	4	54	.078
ATCS Role X Probe X Position	1.092	1.777	0.614	4	54	.654

Appendix H

Conflict Probe and Conflict Resolution Advisory Only

Table H-1. Conflict Probe and Conflict Resolution Advisory: Means and Standard Deviations

CP/ CRA	North Radar						Experimental Position						South Radar						Position Collapsed					
	RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
QY	7.40	2.27	6.59	2.48	6.99	2.35	7.77	3.42	7.87	2.56	7.82	2.94	9.30	1.34	7.39	3.29	8.34	2.64	8.16	2.55	7.28	2.76	7.72	2.67
QKK	7.40	2.63	8.09	1.60	7.75	2.15	8.70	1.25	8.40	1.58	8.55	1.40	7.30	2.75	7.99	2.05	7.65	2.39	7.80	2.33	8.16	1.70	7.98	2.03
QLL	5.90	2.51	6.44	2.31	6.17	2.36	7.48	1.85	7.58	1.90	7.53	1.83	6.40	2.55	7.24	1.96	6.82	2.25	6.59	2.34	7.09	2.05	6.84	2.20
QMM	7.10	1.85	7.89	1.26	7.49	1.59	7.22	2.10	7.22	2.10	7.22	2.04	6.60	2.67	7.29	2.09	6.94	2.36	6.97	2.17	7.47	1.82	7.22	2.00

Table H-2. Conflict Resolution Advisory: MANOVA Results

	Wilks	*F*	df 1	df 2	*p* level
ATCS Role	.949	0.452	3	25	.718
Position	.815	0.896	6	50	.506
ATCS Role X Position	.938	0.270	6	50	.948

Table H-3. Conflict Probe- Conflicting Aircraft Callsign(s): ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	11.476	3.160	3.631	1	27	.067
Position	9.269	10.911	0.849	2	27	.439
ATCS Role X Position	5.075	3.160	1.606	2	27	.219

Table H-4. Conflict Resolution Advisory- Primary Resolution Advisory Control Action for each Aircraft: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	1.958	3.561	0.550	1	27	.465
Position	4.889	4.882	1.001	2	27	.381
ATCS Role X Position	1.640	3.561	0.461	2	27	.636

Table H-5. Conflict Resolution Advisory- Alternate Resolution Advisory Control Action for each Aircraft: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	3.611	3.081	1.172	1	27	.289
Position	9.337	6.588	1.417	2	27	.260
ATCS Role X Position	0.685	3.081	0.222	2	27	.802

Table H-6. Conflict Resolution Advisory- Aircraft Trajectory under Resolution Advisory: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	3.631	2.540	1.429	1	27	.242
Position	1.513	5.907	0.256	2	27	.776
ATCS Role X Position	0.920	2.540	0.362	2	27	.699

Appendix I

Flight Path Monitor Only

Flight Path Monitor Only

Table I-1. Flight Path Deviation: Means and Standard Deviations

FPM	**North Radar**						**Experimental Position**						**South Radar**						**Position Collapsed**					
	RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
QX	5.50	3.14	5.54	3.07	5.52	3.02	6.88	3.35	7.68	2.91	7.28	3.08	7.80	2.78	7.64	2.77	7.72	2.70	6.73	3.14	6.95	3.00	6.84	3.04
QY	5.30	2.75	4.93	2.39	5.12	2.52	5.71	3.02	6.41	2.80	6.06	2.86	7.40	2.67	6.73	2.78	7.07	2.68	6.14	2.87	6.02	2.69	6.08	2.76
QZ	6.50	2.95	6.12	2.67	6.31	2.75	5.86	2.75	6.06	2.99	5.96	2.80	7.60	2.80	7.22	2.91	7.41	2.79	6.65	2.83	6.47	2.81	6.56	2.80
QAA	5.90	3.11	5.06	2.70	5.48	2.87	5.07	3.41	5.27	3.59	5.17	3.41	6.00	3.77	6.66	3.23	6.33	3.44	5.66	3.35	5.66	3.17	5.66	3.23
QBB	5.00	3.27	4.07	2.29	4.53	2.78	5.24	2.78	5.34	3.23	5.29	2.93	6.30	3.53	6.57	3.27	6.43	3.31	5.51	3.15	5.33	3.04	5.42	3.07

Table I-2. Flight Path Deviation: MANOVA Results

	Wilks	*F*	df 1	df 2	*p* level
ATCS Role	.874	0.664	5	23	.655
Position	.702	0.890	10	46	.550
ATCS Role X Position	.631	1.193	10	46	.320

Table I-3. Flight Path Deviation Alert Indicator for Involved Aircraft: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.753	1.245	0.604	1	27	.444
Position	27.157	16.868	1.610	2	27	.218
ATCS Role X Position	1.294	1.245	1.039	2	27	.367

Table I-4. Aircraft Deviation Trajectory: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.188	0.874	0.215	1	27	.646
Position	19.020	14.174	1.342	2	27	.278
ATCS Role X Position	2.585	0.874	2.958	2	27	.069

Table I-5. Aircraft Planned Route: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.508	1.179	0.431	1	27	.517
Position	11.522	15.031	0.767	2	27	.474
ATCS Role X Position	0.553	1.179	0.469	2	27	.631

Table I-6. Extent of Lateral and/or Altitude Deviation: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.001	4.104	0.000	1	27	.986
Position	7.273	17.924	0.406	2	27	.670
ATCS Role X Position	2.949	4.104	0.718	2	27	.497

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Table I-7. Lateral and/or Altitude Deviation Criteria for Alert: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.530	4.063	0.130	1	27	.721
Position	18.296	15.005	1.219	2	27	.311
ATCS Role X Position	2.111	4.063	0.520	2	27	.601

Appendix J

Direct Routing Advisory Only

Direct Routing Advisory Only

Table J-1. Direct Routing Advisory: Means and Standard Deviations

DRA	North Radar						Experimental Position						South Radar						Position Collapsed					
	RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
QX	5.90	2.64	5.48	3.04	5.69	2.78	7.92	2.64	7.92	2.68	7.92	2.59	7.70	3.02	8.28	1.76	7.99	2.42	7.17	2.83	7.23	2.77	7.20	2.77
QY	5.30	2.31	4.98	2.88	5.14	2.55	6.95	2.54	6.45	2.83	6.70	2.63	7.20	3.01	7.88	2.17	7.54	2.58	6.48	2.69	6.44	2.82	6.46	2.73
QZ	6.70	2.41	6.43	3.11	6.57	2.71	6.81	2.35	7.41	2.63	7.11	2.45	7.00	2.67	8.13	1.26	7.57	2.11	6.84	2.39	7.32	2.48	7.08	2.43
QAA	4.50	2.55	5.06	2.81	4.78	2.63	6.81	2.74	7.11	3.14	6.96	2.87	6.00	2.87	7.36	1.96	6.68	2.49	5.77	2.80	6.51	2.79	6.14	2.80
QBB	3.90	2.60	4.37	2.79	4.13	2.64	4.39	2.50	4.69	3.27	4.54	2.84	5.70	2.83	6.47	2.34	6.08	2.56	4.66	2.67	5.18	2.88	4.92	2.77

Table J-2. Direct Routing Advisory: MANOVA Results

	Wilks	*F*	df 1	df 2	*p* level
ATCS Role	.739	1.622	5	23	.194
Position	.529	1.722	10	46	.104
ATCS Role X Position	.733	0.772	10	46	.655

Table J-3. Primary Direct Routing Advisory Control Action for each Aircraft: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.043	1.757	0.024	1	27	.877
Position	34.226	12.428	2.754	2	27	.082
ATCS Role X Position	1.261	1.757	0.718	2	27	.497

Table J-4. Alternate Direct Routing Advisory Control Action for each Aircraft: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	0.029	1.983	0.015	1	27	.905
Position	29.635	11.982	2.473	2	27	.103
ATCS Role X Position	2.030	1.983	1.023	2	27	.373

Table J-5. Aircraft Trajectory under Advisory Route: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	3.572	1.835	1.947	1	27	.174
Position	5.012	10.353	0.484	2	27	.622
ATCS Role X Position	2.497	1.835	1.361	2	27	.273

Table J-6. Actual Time and Distance Savings with Advisory Route: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	8.155	2.972	2.744	1	27	.109
Position	28.235	11.634	2.427	2	27	.107
ATCS Role X Position	1.517	2.972	0.510	2	27	.606

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Table J-7. Time and Distance Savings Criteria for Aircraft Identification: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	3.932	2.644	1.487	1	27	.233
Position	21.156	12.352	1.713	2	27	.199
ATCS Role X Position	0.281	2.644	0.106	2	27	.900

Appendix K

Load Smoother Advisory Only

Load Smoother Advisory Only

Table K-1. Load Smoother Advisory: Means and Standard Deviations

LS	North Radar						Experimental Position						South Radar						Position Collapsed					
	RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.		RC		AC		Funct. Coll.	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
QX	5.60	2.07	7.76	2.13	6.68	2.33	8.17	2.26	9.07	1.04	8.62	1.77	7.20	3.01	8.16	1.80	7.68	2.46	6.99	2.62	8.33	1.75	7.66	2.31
QY	5.00	2.26	6.56	1.83	5.78	2.16	7.09	1.91	8.39	1.28	7.74	1.72	6.60	3.06	7.76	2.12	7.18	2.63	6.23	2.54	7.57	1.88	6.90	2.32
QZ	5.80	2.39	7.38	2.07	6.59	2.32	6.89	2.33	7.79	1.62	7.34	2.01	5.80	2.62	7.98	1.72	6.89	2.43	6.16	2.42	7.72	1.77	6.94	2.24
QAA	5.80	2.74	7.69	2.09	6.75	2.56	6.85	2.45	8.75	1.09	7.80	2.09	7.00	3.06	8.79	1.19	7.90	2.44	6.55	2.72	8.41	1.56	7.48	2.39

Table K-2. Load Smoother Advisory: MANOVA Results

	Wilks	*F*	df 1	df 2	*p* level
ATCS Role	.620	3.674	4	24	.018
Position	.621	1.614	8	48	.146
ATCS Role X Position	.586	1.838	8	48	.093

Table K-3. Primary Load Smoother Advisory Control Action for each Aircraft: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	27.041	2.402	11.256	1	27	.002
Position	18.709	6.697	2.794	2	27	.079
ATCS Role X Position	2.535	2.402	1.055	2	27	.362

Table K-4. Alternate Load Smoother Advisory Control Action for each Aircraft: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	26.934	2.974	9.056	1	27	.006
Position	20.384	6.225	3.274	2	27	.053
ATCS Role X Position	0.206	2.974	0.069	2	27	.933

Table K-5. Aircraft Trajectory under Advisory Route: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	36.069	3.212	11.231	1	27	.002
Position	2.898	6.080	0.477	2	27	.626
ATCS Role X Position	2.038	3.212	0.634	2	27	.538

Table K-6. "Hot Spots" under Advisory Route for Specific Times: ANOVA Results

	MS Effect	MS Error	*F*	df 1	df 2	*p* level
ATCS Role	51.968	3.594	14.461	1	27	.001
Position	8.129	6.340	1.282	2	27	.294
ATCS Role X Position	0.018	3.594	0.005	2	27	.995

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